Total Maximum Daily Loads (TMDLs) for Total Suspended Solids, Nitrogen and Phosphorus in Kapa'a Stream Kailua, Hawaii

Draft Report for Public Review

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Executive Summary

This report reviews historical and existing conditions in the Kapa'a watershed on the island of Oahu, Hawaii and presents an analysis of pollutant load distributions and resulting water quality in Kapa'a Stream. Calculations of pollutant load capacities are provided, and of their allocations to identified pollutant sources such that water quality standards for total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP) in Kapa'a Stream will be achieved.

The primary data source for this report was the 2002 report, "Kapa'a Stream Hydrology, Biology and Water Quality Survey," commissioned by Ameron Hawaii and prepared by Oceanit Laboratories, Inc. with AECOS, Inc. as part of an enforcement settlement agreement between Ameron and the State of Hawaii Department of Health.

The State of Hawaii Department of Health, in its Final 2004 List of Impaired Waters in Hawaii prepared under Clean Water Act §303(d), identified water quality in Kapa'a Stream as impaired by elevated turbidity, total suspended solids (TSS), nutrients (TN, TP), and metals. Subsequent review of toxic metals standards and data relative to total hardness (calcium + magnesium) present in Kapa'a Stream found the stream not impaired by excessive metals.

The Kapa'a watershed area is 825 acres (about 1.3 square miles) on the windward side of Oahu, Hawaii. Kapa`a Stream flows to the Kawainui Marsh and beyond to the Oneawa Canal, Kailua Bay, and the Pacific Ocean. The stream has a total length of about 2 miles with baseflow averaging about 1 cubic foot per second (cfs) beginning at an elevation of about 115 feet near the central part of the watershed. During non-runoff conditions this baseflow is sufficient to feed at least two year-round pools along its length before entering a permanent channel at sea level of Kawainui Marsh.

Development in the Kapa'a watershed during the past 60 years has included major quarry operations in two locations, two municipal sanitary landfills, one unrecorded County refuse disposal landfill, deposition of quarry materials over wetlands and mid-valley stream course, construction of a federal highway through the center of the valley, and the development of multiple light industrial business uses on lands filled over the historical streambed. All of these activities have had significant impacts on the stream and water quality. It is doubtful that any significant length of the present streambed is in its original condition or location.

Baseflow and pollutant load contributions were calculated for individual land use areas during dry season (May-October) and wet season (November-April) non-runoff conditions. Baseflow volume contributions are roughly proportional to the size of their contributing areas. Relative nitrogen and phosphorus contributions (33% and 41%, respectively) from landfill areas are greater than their area proportion (22%); relative nitrogen and phosphorus contributions (20% and 27%, respectively) from forest/brush-covered areas are significantly less than their area proportion (41%). Baseflow concentrations of total nitrogen and total phosphorus exceed water quality targets in most of the length of Kapa'a Stream during dry and wet seasons. Baseflow concentrations of total suspended solids exceed the dry season baseflow target very slightly at two locations and are well below the wet season target at all locations.

Storm runoff, pollutant loads, stream flows, and concentrations of total suspended solids, nitrogen, and phosphorus were calculated for four 24-hour rainfall events: 0.35-inch (dry season 10%

event), 1.27-inch (dry season 2% event), 0.70-inch (wet season 10% event), and 2.30-inch (wet season 2% event). These calculations take into account the runoff and sediment retention systems that are present in the Kapa'a watershed. From the 0.35-inch rainfall, very slight runoff occurs only from the 5% of the watershed that is highway or road area; pollutant loads are 0.35 kg TSS and less than 0.01 kg TN or TP. As rainfall increases to the 2.30-inch event, runoff discharged increases to a million cubic feet (mcf); discharged loads of suspended solids increase to 71,000 kg; total nitrogen and phosphorus loads increase to 81 and 35 kg, respectively. Primary sources of discharged runoff volumes (60%) and pollutant loads (96% TSS, 75% TN, 71% TP) are the Kapa'a and Kalaheo landfill areas and the area of off-road vehicular erosion in Sub-basin D.

Load capacities for TSS, TN, and TP were calculated as the maximum amount of pollutant loads that will be allowable without violating the water quality targets in each of six Kapa'a stream segments and in the direct discharge to Kawainui Marsh from the Sub-basin L area (lower Kapaa landfill and solid waste transfer station). Allocations to individual land use areas were calculated as the lesser of the proportion of existing load to stream segment load capacity or the existing load from the area. This allocation procedure both recognizes the antidegradation policy in the water quality standards and provides a substantial margin of safety for achieving the numeric water quality targets. The summations of these thus calculated allocations for each pollutant are the TMDLs for TSS, TN, and TP for the Kapa'a watershed.

The TMDL allocations for each land use area in each sub-basin are consolidated into wasteload allocations (WLAs) to identified NPDES permit service areas and load allocations (LAs) to the nonpoint source areas not directly regulated by Clean Water Act permit. These consolidated allocations and the load reductions required for their achievement under critical dry season and wet season conditions are summarized in the tables below. Implementation of the required load reductions will result in attainment of the water quality standards for TSS, TN, and TP in Kapa'a Stream and other inflows to Kawainui Marsh from the Kapa'a watershed area.

Wasteload allocations (WLAs) for the Kapa'a Stream TMDLs will be implemented through compliance with NPDES permit conditions and by following the stormwater management plans associated with those permits. It will be necessary to revise most of these permits to include effluent limitations consistent with the approved WLAs, as required by federal regulations at 40 CFR 122.44 (d)(1). Load allocations may be implemented through a variety of voluntary approaches to polluted runoff control, as described in general by Hawaii's Implementation Plan for Polluted Runoff Control (Coastal Zone Management Program and Polluted Runoff Control Program, 2000) and Hawaii's Coastal Nonpoint Pollution Control Program Management Plan (Hawaii Coastal Zone Management Program, 1996), both of which are being revised and updated to better address the implementation of TMDL allocations. Specific measures for reducing pollutant loads in the Kapa'a watershed are identified in the Ko'olaupoko Water Quality Action Plan (Kailua Bay Advisory Council, 2002) and the Kailua Waterways Improvement Plan, Strategic Implementation Plan, and BMP Manual (Tetra Tech EM, Inc., 2003). They will also be a focus of future watershed-based plans and TMDL implementation plans (State of Hawaii Department of Health). By addressing the nine elements required by EPA guidance and incorporating the LA objectives from Tables 6.10 and 6.11 (see below), these plans can unlock the door to additional Clean Water Act §319(h) incremental funds for water quality improvement projects. Such projects may also qualify for the DOH Clean Water State Revolving Fund Program, which provides low interest loans for the construction of point source and non-point source water pollution control projects.

Dry weather baseflow augmentation from waters collected in the Ameron Hawaii Phase I quarry pit may improve Kapa'a Stream water quality during dry weather conditions, and this approach deserves further analysis in the context of overall Kawainui Marsh management goals and the available mechanisms for modifying Ameron's current NPDES permit. Future Kawainui Marsh management planning may also benefit from additional attention to the effects of wet weather loading from the quarry and landfills during extreme events and to the constant flux of quarry and landfill-influenced groundwater.

Consolidated Dry Season TMDL Allocations to Existing Sources and
Load Reductions Required to Achieve Kapaa Stream TMDLs (Table 6.10, page 6-11)*

Dry Season Baseflow	**TMDLs**			**Existing Loads**			**Reductions Required**					
	TSS	**TN**	**TP**	**TSS**	**TN**	**TP**	**TSS**		**TN**		**TP**	
LAs to facility areas	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	*(%)*	(kgd)	*(%)*	(kgd)	*(%)*
CCH MS4 area	5	0.0	0.0	5	0.1	0.0	1	11	0.1	83	0.0	85
CCH Kalaheo Landfill	19	0.1	0.0	24	0.5	0.2	5	20	0.5	85	0.2	87
CCH Kapa'a Landfill	27	0.1	0.0	36	0.9	0.3	9	25	0.8	89	0.3	91
CCH Waste Transfer	1	0.0	0.0	23	0.3	0.1	22	95	0.3	94	0.1	96
HI DOT Highways MS4	4	0.0	0.0	4	0.1	0.0	0	4	0.1	79	0.0	81
Ameron Quarry	62	0.2	0.1	69	1.4	0.3	7	10	1.2	85	0.2	81
Industrial Park	22	0.1	0.0	28	0.4	0.1	5	19	0.3	85	0.1	87
LA to other source areas	40	0.3	0.1	41	1.0	0.4	1	2	0.7	70	0.3	71
Totals	**180**	**0.8**	**0.2**	**229**	**4.6**	**1.4**	**49**	***21***	**3.9**	***83***	**1.2**	***83***
Dry Season 10% Runoff	**TMDLs**			**Existing Loads**			**Reductions Required**					
	TSS	**TN**	**TP**	**TSS**	**TN**	**TP**	**TSS**		**TN**		**TP**	
WLAs	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	*(%)*	(kg)	*(%)*	(kg)	*(%)*
CCH MS4	0.1	0.0	0.0	0.1	0.0	0.0	0.0	13	0.0	10	0.0	13
CCH Kalaheo Landfill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0
CCH Kapa'a Landfill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0
CCH Waste Transfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0
HIDOT Highways MS4	0.2	0.0	0.0	0.3	0.0	0.0	0.0	5	0.0	4	0.0	6
Ameron Quarry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0
Industrial Park	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0
LA to Nonpoint sources	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0
Totals	**0.3**	**0.0**	**0.0**	**0.4**	**0.0**	**0.0**	**0.0**	***7***	**0.0**	***5***	**0.0**	***7.2***
Dry Season 2% Runoff	**TMDLs**			**Existing Loads**			**Reductions Required**					
	TSS	**TN**	**TP**	**TSS**	**TN**	**TP**	**TSS**		**TN**		**TP**	
WLAs	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	*(%)*	(kg)	*(%)*	(kg)	*(%)*
CCH MS4	61	0.2	0.1	384	0.7	0.5	323	84	0.5	68	0.4	90
CCH Kalaheo Landfill	0	0.0	0.0	0	0.0	0.0	0	0	0.0	0	0.0	0
CCH Kapa'a Landfill	80	0.8	0.1	3586	4.9	1.3	3506	98	4.0	83	1.2	92
CCH Waste Transfer	3	0.1	0.0	49	0.3	0.1	46	95	0.2	71	0.1	85
HIDOT Highways MS4	49	0.5	0.2	68	0.7	0.7	19	28	0.2	22	0.5	76
Ameron Quarry	0	0.0	0.0	0	0.0	0.0	0	0	0.0	0	0.0	0
Industrial Park	133	0.6	0.1	272	1.7	0.3	139	51	1.1	63	0.3	82
LA to Nonpoint sources	434	2.2	0.3	8545	5.0	3.5	8111	95	2.9	57	3.2	91
Totals	**760**	**4.5**	**0.7**	**12904**	**13.3**	**6.3**	**12144**	***94***	**8.8**	***66***	**5.7**	***89***

*TMDL allocations in kilograms pre day (kgd) are obtained by dividing dry season kilograms (kg) by 184 days. Loads and Load Reductions are rounded to the nearest 0.1 kg, thus (a) **Totals** may be different than the sum of their parts and (b) **TMDLs**, **Existing Loads** and **Reductions Required** may actually be greater than 0.

Acronyms

TMDLs = Total Maximum Daily Loads
LA = Load Allocation
WLAs = Waste Load Allocations
TN = Total Nitrogen
TP = Total Phosphorous
CCH = City and County of Honolulu
MS4 = Municipal Separate Storm Sewer System
TSS = Total Suspended Solids
HIDOT = State of Hawaii Department of Transportation

Consolidated Wet Season TMDL Allocations to Existing Sources and
Load Reductions Required to Achieve Kapaa Stream TMDLs (Table 6.11, page 6-12)*

Wet Season Baseflow	**TMDLs**			**Existing Loads**			**Reductions Required**					
	TSS	**TN**	**TP**	**TSS**	**TN**	**TP**	**TSS**		**TN**		**TP**	
LAs to facility areas	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	*(%)*	(kgd)	*(%)*	(kgd)	*(%)*
CCH MS4	7	0.0	0.0	7	0.1	0.0	0	0	0.1	81	0.0	82
CCH Kalaheo Landfill	34	0.1	0.1	34	0.8	0.3	0	0	0.6	82	0.3	83
CCH Kapa'a Landfill	39	0.2	0.1	52	1.3	0.5	13	25	1.2	87	0.4	88
CCH Waste Transfer	3	0.0	0.0	27	0.4	0.1	24	89	0.3	92	0.3	95
HI DOT Highways MS4	5	0.0	0.0	5	0.1	0.0	0	0	0.1	76	0.0	76
Ameron Quarry	91	0.3	0.1	91	1.2	0.4	0	0	1.5	82	0.3	75
Industrial Park	31	0.1	0.0	31	0.4	0.1	0	0	0.4	82	0.1	83
LA to other source areas	59	0.5	0.2	59	1.4	0.5	0	0	1.0	69	0.3	66
Totals	**269**	**1.2**	**0.4**	**306**	**6.3**	**1.9**	**37**	***12***	**5.1**	***81***	**1.5**	***79***
Wet Season 10% Runoff	**TMDLs**			**Existing Loads**			**Reductions Required**					
	TSS	**TN**	**TP**	**TSS**	**TN**	**TP**	**TSS**		**TN**		**TP**	
WLAs	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	*(%)*	(kg)	*(%)*	(kgd)	*(%)*
CCH MS4	22	0.1	0.0	113	0.2	0.2	91	80	0.1	61	0.1	83
CCH Kalaheo Landfill	0	0.0	0.0	0	0.0	0.0	0	0	0.0	0	0.0	0
CCH Kapa'a Landfill	16	0.2	0.0	902	1.2	0.3	886	98	1.1	87	0.3	90
CCH Waste Transfer	0	0.0	0.0	0	0.0	0.0	0	0	0.0	0	0.0	0
HIDOT Highways MS4	17	0.2	0.1	23	0.2	0.2	6	27	0.1	28	0.1	60
Ameron Quarry	0	0.0	0.0	0	0.0	0.0	0	0	0.0	0	0.0	0
Industrial Park	63	0.2	0.0	89	0.6	0.1	26	29	0.3	59	0.1	65
LA to Nonpoint sources	119	0.3	0.1	2252	1.2	0.9	2134	95	0. 9	74	0.8	92
Totals	**237**	**1.0**	**0.3**	**3379**	**3.4**	**1.7**	**3142**	***93***	**2. 5**	***72***	**1.5**	***85***
Wet Season 2% Runoff	**TMDLs**			**Existing Loads**			**Reductions Required**					
	TSS	**TN**	**TP**	**TSS**	**TN**	**TP**	**TSS**		**TN**		**TP**	
WLAs	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	*(%)*	(kg)	*(%)*	(kg)	*(%)*
CCH MS4	258	1.3	0.4	1926	3.2	2.1	1668	87	2.0	61	1.7	83
CCH Kalaheo Landfill	136	1.4	0.2	3154	4.6	1.3	3018	96	3.3	71	1.1	84
CCH Kapa'a Landfill	800	7.1	1.3	22726	30.9	8.2	21926	96	23.8	77	6.9	84
CCH Waste Transfer	42	1.3	0.3	806	4.8	1.3	765	95	3.4	72	1.1	80
HIDOT Highways MS4	212	2.2	1.1	268	2.7	2.7	56	21	0.5	17	1.6	59
Ameron Quarry	0	0.0	0.0	0	0.0	0.0	0	0	0.0	0	0.0	0
Industrial Park	530	3.5	0.4	1239	7.8	1.6	710	57	4.3	55	1.2	75
LA to Nonpoint sources	6516	15.6	3.8	41164	27.3	18.2	34648	84	11.7	43	14.4	79
Totals	**8494**	**323**	**7.4**	**71284**	**81.2**	**35.4**	**62790**	***88***	**48.9**	***60***	**28.0**	***79***

*TMDL allocations in kilograms pre day (kgd) are obtained by dividing wet season kilograms (kg) by 181 days.
Loads and Load Reductions rounded to the nearest kg, thus (a) **Totals** may be different than the sum of their parts and (b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

<ins>Acronyms</ins> – see Dry Season Table above

As required by the Code of Federal Regulations (C.F.R.) and Hawaii Administrative Rules (HAR), 40 C.F.R. sec. 122.44(d)(1)(vii)(B) and HAR sec. 11-55-19(a)(4)(C), and intended by Hawaii's Continuing Planning Process for Surface Water Pollution Control (approved by EPA June 14, 1976 and last reviewed by EPA in August 2001), upon approval of a TMDL by EPA, the TMDL Waste Load Allocations (WLAs) are immediately effective to be applied in National Pollutant Discharge Elimination System (NPDES) permits. NPDES permits issued by the DOH shall include limitations needed to implement the WLAs in TMDLs, and the Department of Health (DOH) shall enforce these limits.

The State will assure implementation of the approved TMDL WLAs through the enforcement of NPDES permit conditions (HAR §11-55) and will pursue implementation of load allocations through Hawaii's Implementation Plan for Polluted Runoff Control (Coastal Zone Management Program and

Polluted Runoff Control Program, 2000) and Hawaii's Coastal Nonpoint Pollution Control Program Management Plan (Hawaii Coastal Zone Management Program, 1996), all of which serve the State Water Quality Standards (HAR §11-54

Chapter 1
Introduction

1.1 Location

The Kapa`a Stream watershed is on the windward (northeast) side of the Island of Oahu, Hawaii, on the outskirts of the Kailua secondary urban center (Figure 1.1). Kapa`a Stream drains directly to Kawainui Marsh, the largest freshwater wetland in Hawaii and one with significant cultural and wildlife resources. A portion of the groundwater infiltrating from the Kapa'a watershed also drains eastward to the marsh. The waters of Kawainui Marsh drain through the man-made Oneawa channel to the Pacific Ocean at the northwest end of Kailua Beach.

1.2 Problem Statement

Kapa'a Stream is included in Hawaii's 2004 Section 303(d) List of Impaired Waters because of elevated concentrations of turbidity, suspended solids, nutrients, and metals in the stream. High levels of turbidity and suspended solids have historically resulted from storm runoff and discharges of wash water from quarry operations in the watershed. Nutrient (nitrogen and phosphorus) and metals contamination have been found in monitoring wells around the unlined landfills adjacent to the stream. Other sources of water contamination include a number of light industry operations in the lower watershed and areas of erosion within upstream conservation lands.

Water pollutants in the Kapa'a watershed are a concern not only for the quality of the waters of Kapa'a Stream but also for their adverse impacts on the waters of Kawainui Marsh (Class 1.b. State waters and a wetland of international importance under the Ramsar Convention) and Kailua Bay. The purpose of this report is to identify the total loads of suspended solids, nitrogen, phosphorus, and metals that can be delivered to Kapa'a Stream without violating Hawaii's water quality standards, and to allocate these allowable loads among the several watershed sources. A further intent of the report is to provide source analysis detail that will assist the implementation planning for each source and the TMDL development process for Kawainui Marsh and Kailua Bay.

1.3 Water Quality Standards

TMDLs are established to achieve and maintain water quality standards. A water quality standard consists of the designated use(s) for the water, water quality criteria designed to protect the use(s), and an antidegradation policy. Kapa`a Stream is a Class 2 Inland Stream (DOH Water Quality Standards §11-54-5.1). The objectives of Class 2 waters, as they apply to Kapa`a Stream, are to protect its uses for recreational purposes, the support and propagation of fish and other aquatic life, and agricultural and industrial water supplies. Uses to be protected include all uses compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. Agriculture was a major historical use but there are known existing agricultural or industrial uses of Kapa`a Stream waters at present. Existing uses include support of recreational activities, aesthetic values, and traditional and customary native Hawaiian beliefs, values, and practices.

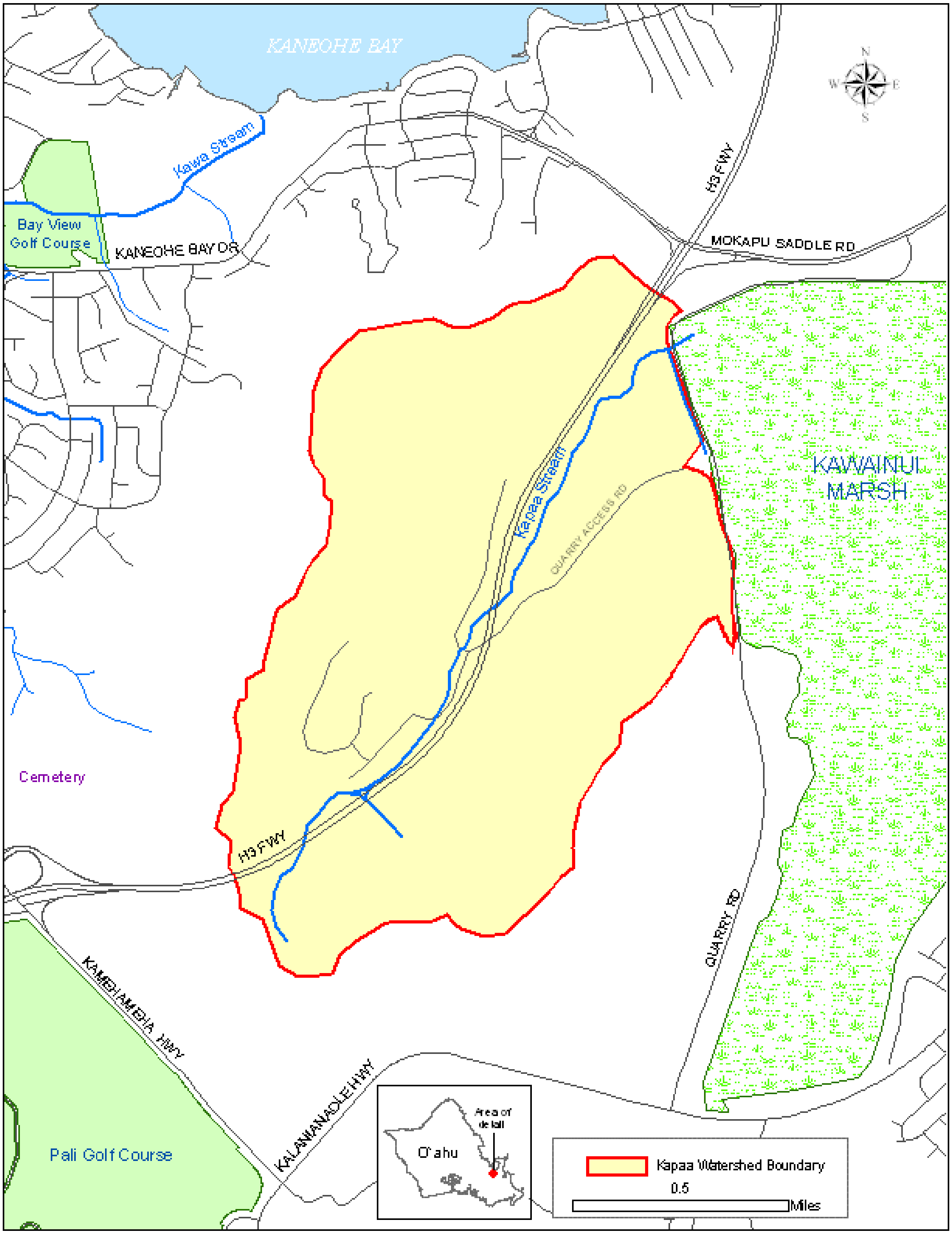


Figure 1.1. Kapa'a site location map.

Kapa`a Stream, like most Hawaii perennial streams, is characterized by periods of relatively steady base flow interspersed with short periods of high flow (termed freshets) resulting from heavy rains in the watershed. Physical and chemical properties of the stream water can vary between these two types of flow, as well as between storms of different magnitudes and at different times during storm flow. The base flow from headwater springs is small in Kapa`a so the stream is perennially flowing only in its lower downstream reaches.

Water quality standards for Hawaii streams first approximated their existing form in 1979 and were last revised in 2004 (Hawaii Administrative Rules Title 11, Department of Health Chapter 54 Water Quality Standards, §11-54-5.2). Four parameters (temperature, pH, dissolved oxygen, salinity) have limits defined by specific upper or lower bounds. Nine other parameters, including turbidity, total nitrogen, total phosphorus, and total suspended solids in streams, are defined by three numeric criteria – a geometric mean and two exceedance values (10% and 2%) - for each of two seasons, wet and dry. The water quality criteria for these parameters are displayed in Table 1.1, where terms have the following meanings:

1. Geometric mean (GM). The geometric mean of all time-averaged samples should not exceed this value. The geometric mean is calculated as the *n*th root of all samples, where *n* represents the total number of samples.

2. 10% exceedance value. No more than 10% of all time-averaged samples should exceed this value.

3. 2% exceedance value. No more than 2% of all time-averaged samples should exceed this value.

Table 1.1. State of Hawaii Water Quality Standards for Streams

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than 10% of the time	Not to exceed the given value more than 2% of the time
Total Nitrogen (ug N/l)	250* 180**	520 380	800 600
Nitrate + Nitrite (ug N/l)	70 30	180 90	300 170
Total Phosphorus (ug P/l)	50 30	100 60	150 80
Total Suspended Solids (mg/l)	20 10	50 30	80 55
Turbidity (Nephelometric turbidity units)	5 2	15 5.5	25 10
* upper number = wet season ** lower number = dry season	Nov 1- Apr 30 May 1 - Oct 31		

The freshwater stream criteria for metals in Hawaii's Water Quality Standards are displayed in Table 1.2, where terms have the following meanings:

Acute Toxicity Standard.	All state waters shall be free from pollutants in concentrations which exceed the acute value listed.
Chronic Toxicity Standard.	All state waters shall be free from pollutants in concentrations which on average during any 24-hour period exceed the chronic value listed.

Table 1.2. State of Hawaii Freshwater Acute and Chronic Standards for Metals

All concentrations in micrograms per liter, ug/l	Acute	Chronic	Acute	Chronic
			Total hardness = 100 mg/l*	
Aluminum	750	260		
Antimony	3000	ns		
Arsenic	360	190		
Cadmium	3+	3+	2	0.25
Chlorine	19	11		
Copper	6+	6+	13	9
Chromium (VI)	16	11		
Cyanide	22	5.2		
Lead	29+	29+	65	2.5
Mercury	2.4	0.55		
Nickel	5+	5+	470	52
Selenium	20	5		
Silver	1+	1+	3.2	1.9
Zinc	22+	22+	120	120

* See explanation below.
\+ Minimum standard. Depending upon receiving water hardness, more restrictive standards may be calculated.

After accounting for water hardness in Kapa'a Stream (EPA 2004), the standards for some metals of concern in the stream, i.e., copper, nickel, zinc, remain at the prescribed minimum while the standards for other metals, i.e., cadmium, lead (chronic), become restricted to less than the minimum levels listed in Table 1.2. (results for 100 mg/l as $CaCO_3$ displayed in the two right-hand columns of Table 1.2). Observed metals concentrations (Table 4.3) do not appear to have exceeded the hardness-accounted water quality standards so TMDLs were not developed for metals. It should be noted however that low or absent metals in the water column does not provide complete information about the presence of metals in the environment. Metals contamination may be relatively high in sediments and in the biological food web that feeds on these sediments without this contamination being necessarily reflected in the water column.

1.4 Background Studies

In December 2002, Oceanit Laboratories, Inc. and Aecos, Inc. completed a "Kapa'a Stream Hydrology, Biology, and Water Quality Survey" for Ameron, Hawaii (Oceanit 2002). That survey is a primary information source for this report and data from the survey are summarized in Chapter 4. Other sources of information used include NPDES permit documentation, individual wastewater system documentation, site investigation reports, historic ecosystem and planning studies of the Kawainui Marsh region, and various aerial photography, mapping, and hydrologic data products.

1.5 Report Organization

This report is divided into seven (7) chapters and a technical appendix. Chapter 1, Introduction, defines the environmental problem addressed by the report and identifies the water quality standards that are the objectives of the TMDLs that are developed. Chapter 2, Setting, describes the physical and cultural context of the watershed and the climate conditions that express the seasonal variation and critical conditions for which the TMDLs are developed. Chapter 3, Source Descriptions, defines stream segments and tributary subbasin areas and identifies the sources of pollutants. This chapter provides the organizational basis for the TMDL analysis and development. Chapter 4, Water Quality Data, summarizes the available data from the 2002 Oceanit Survey. Chapter 5, Existing Conditions, develops the quantitative descriptions of hydrology and pollutant loads and presents the calculations of streamflow and existing water quality for critical dry season and wet season conditions. Chapter 6, TMDL Allocations, develops the numeric TMDL targets and the pollutant load capacities for Kapa’a Stream for the critical water quality conditions. Allocations of pollutant load capacities to individual sources are then calculated and these allocations are consolidated into areas serviced by NPDES permits. Regulatory or other mechanisms through which the TMDL allocations will be implemented are described and the agencies that will be responsible for the implementation are identified. Chapter 7, Public Participation, summarizes DOH communication and interaction with the general public about the TMDL process and related environmental health concerns, and includes a complete record of the public notices, public information meetings, public review comments, and agency responses associated with TMDL development. A Technical Appendix develops the background mathematical relationships that are used to calculate runoff, pollutant loadings, streamflows, water quality, and TMDL allocations.

The report was prepared by Jack D. Smith (DOH contractor), David C. Penn and Glen Fukunaga (DOH Environmental Planning Office). We gratefully acknowledge assistance from Wanda Chang and the Environmental Health Analytical Services Branch staff (DOH State Laboratories Division); Leanne Watanabe and Joanna Seto (DOH Clean Water Branch); Clarence Callahan and Melody Calisay (DOH Hazard Evaluation and Emergency Response Office); Lene Ichinotsubo, Sue Liu, Jose Ruiz, Gary Siu, and Janis Fujimoto (DOH Solid and Hazardous Waste Branch), Linda Koch (DOH Environmental Planning Office), Lance Tauoa (formerly DOH Environmental Planning Office), Linda Goldstein (Ameron Hawaii, Inc.), Gerald Takayesu, Randall Wakumoto, Wayne Hamada, and John Nolan (City & County of Honolulu), Dean Yanagisawa (formerly State of Hawaii Department of Transportation), Larissa Sato (Parsons Brinckerhoff Quade & Douglas, Inc.), Robert Bourke (Oceanit Laboratories, Inc.), Martha Yent (State of Hawaii Department of Land and Natural Resources), Jim Corcoran (City & County of Honolulu, Kailua Neighborhood Board), Shannon and Jim Wood (Windward Ahupua’a Action Alliance), John T. King (Kapaa 1, LLC), and Sarah Perry (Prescott College). This work was funded by the EPA through the FY-05 and FY-06 Water Pollution Control program grant to DOH (Clean Water Act §106) and by State budgeting for staff positions and office support within DOH.

Chapter 2
Setting

2.1 Kapa’a Watershed

The Kapa`a Stream watershed is an area of about 1.3 square miles (825 acres) on the windward side of the Island of Oahu, Hawaii (Figure 1.1). Kapa`a Stream drains directly to Kawainui Marsh and infiltrated water from the Kapa’a watershed drains indirectly to the marsh. The 1,000-acre Kawainui Marsh is the largest freshwater wetland in the State, habitat for four of Hawaii’s endemic and endangered waterbirds, and a place sacred to Native Hawaiians. Kawainui, with its adjacent Hamakua Marsh, are a designated “Wetland of International Importance” (USFWS 2005).

2.2 History

Early Hawaiians occupied the Kapa’a watershed area as long ago as ca. 500 AD. The legendary ruler, Olopana, lived in the Kapa’a valley during that time. The present marsh was then a lagoon open to the sea. Over the ensuing centuries, the lagoon slowly filled in to become the present Kawainui Marsh and the land beneath the town of Kailua that now separates the marsh from the sea. In the 16th century, this area was the home of the Oahu *ali’i*, Hawaiian chiefs.

Early in the 16th century, each of the islands of Hawaii came to be divided into *moku*, or separate districts, each ruled by its individual chief. These *moku* were subdivided into smaller sections called *ahupua’a,* now the most commonly recognized of the early land divisions. As a fundamental unit of community subsistence and political organization, *ahupua’a* typically describes a section of land running *mauka makai*, from the mountain into the sea to the outer edge of the reef. Forests on the mountain provide wood for canoes, housing, implements, and fire. Taro and other foods and fiber grow in the valley's *lo’i kalo* (irrigated pondfields). Fish, salt, and *limu* (edible seaweed) are harvested from the sea. Through the center of many *ahupua’a* runs a stream, the most important and protected resource of the *ahupua’a*. The idea of TMDL, with allocations of resource protection obligations and watershed-based resource management, echoes the beliefs, values, and practices of early Hawaiian culture.

Moku and *ahupua’a* of the island of Oahu are shown in Figure 2.1. based on this figure, Kapa’a Stream is a part of the Kailua *ahupua’a* that lies within the *moku* of Ko’olaupoko. . The northwestern boundary of the Kapa’a watershed is the Mahinui ridgeline, separating Kapa’a from the Kawa Stream watershed in the Kane’ohe *ahupua’a*. Between Kapa’a and Kawainui Marsh to the southeast is the hilly place known as Ulumawao. Agricultural cultivation was an important activity in the Kapa’a valley from its earliest settlement until midway through the last century. Cattle were ranged in the area during the first half of the century until Kaneohe Ranch closed down its cattle raising operations in 1942. The rapid subsequent changes in land use and character of Kapa’a valley are documented in a series of aerial photographs (Oceanit 2002).

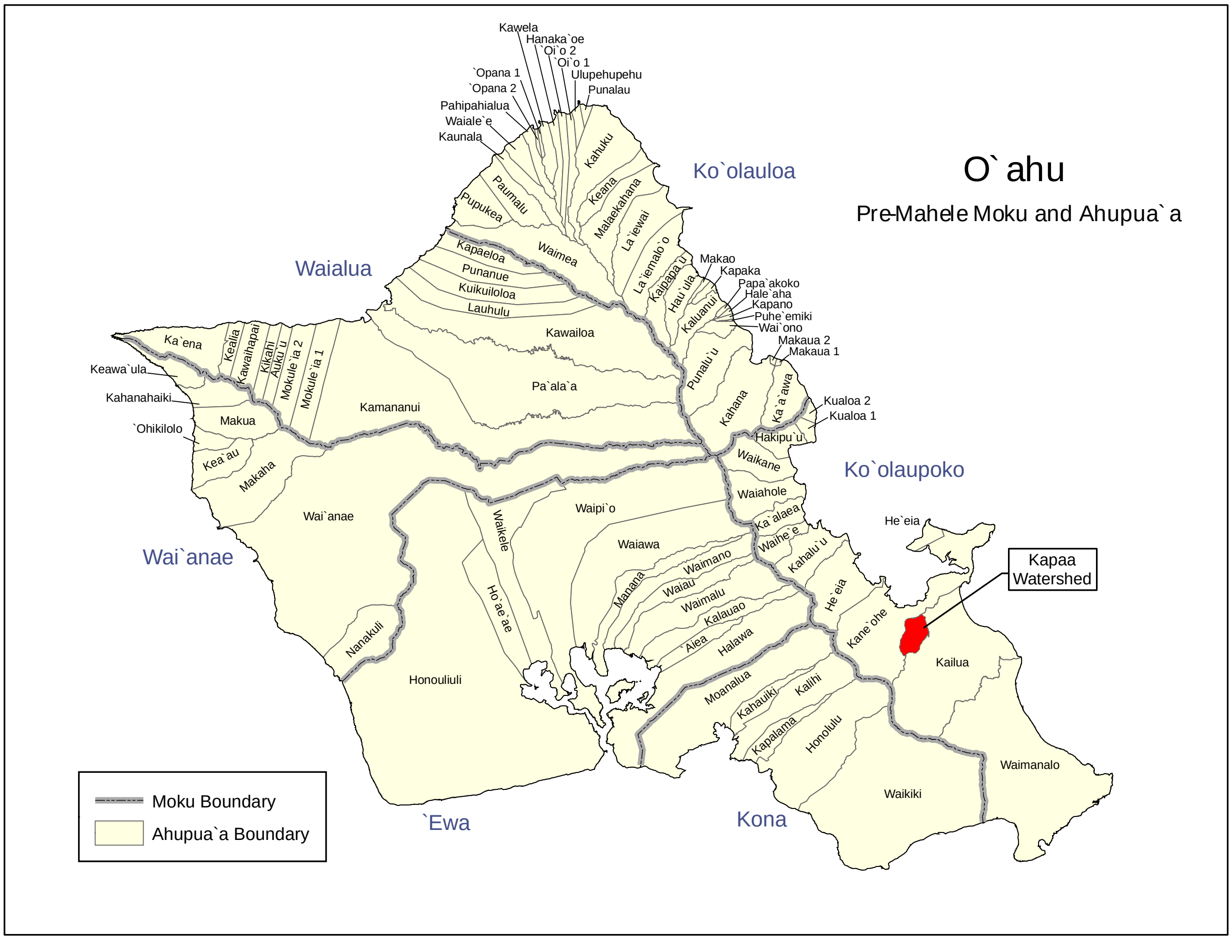


Figure 2-1. The *moku* and *ahupua'a* of Oahu

The photograph of Kapa'a valley in 1949 (Figure 2-2) shows agricultural use on about 75 acres in the middle and lower valley, with no development in the upper valley other than a single dirt road providing access to Kamehameha Highway. The agricultural lots are contiguous with the main body of the Kawainui Marsh and a faint stream channel can be seen through the wetland grass at the center of the valley where it meets the wetland.

In the 1952 photograph the first Kapa`a quarry operations (begun in late 1949) can be seen at the foot of Ulumawao just above the marsh. A raised roadbed has been constructed, segregating approximately 35 acres of wetland from the main Kawainui Marsh and creating an open water drainage canal along the upstream side of the new road. At this time, there is still active farming in the valley and the addition of one house lot near the north end of the newly constructed road. The lower Kapa'a stream course appears as a straight drainage channel through the middle of the now enclosed agricultural fields and wetland at the center of the valley. There appears to be no change in the course of the midstream channel through the agriculture lots.

Figure 2-2. 1949 aerial photo of lower Kapa`a valley.

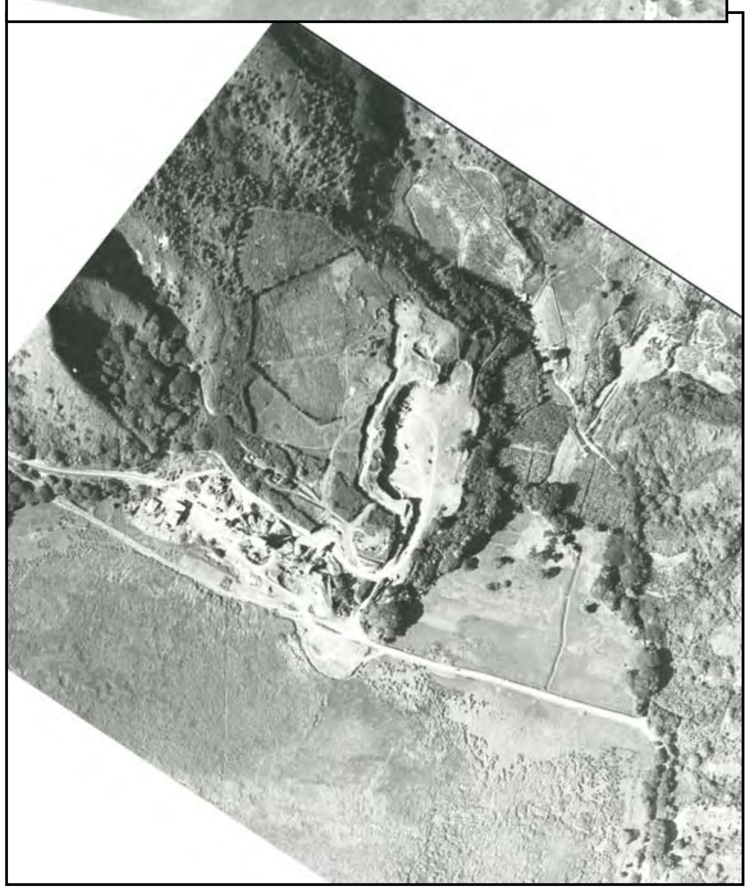
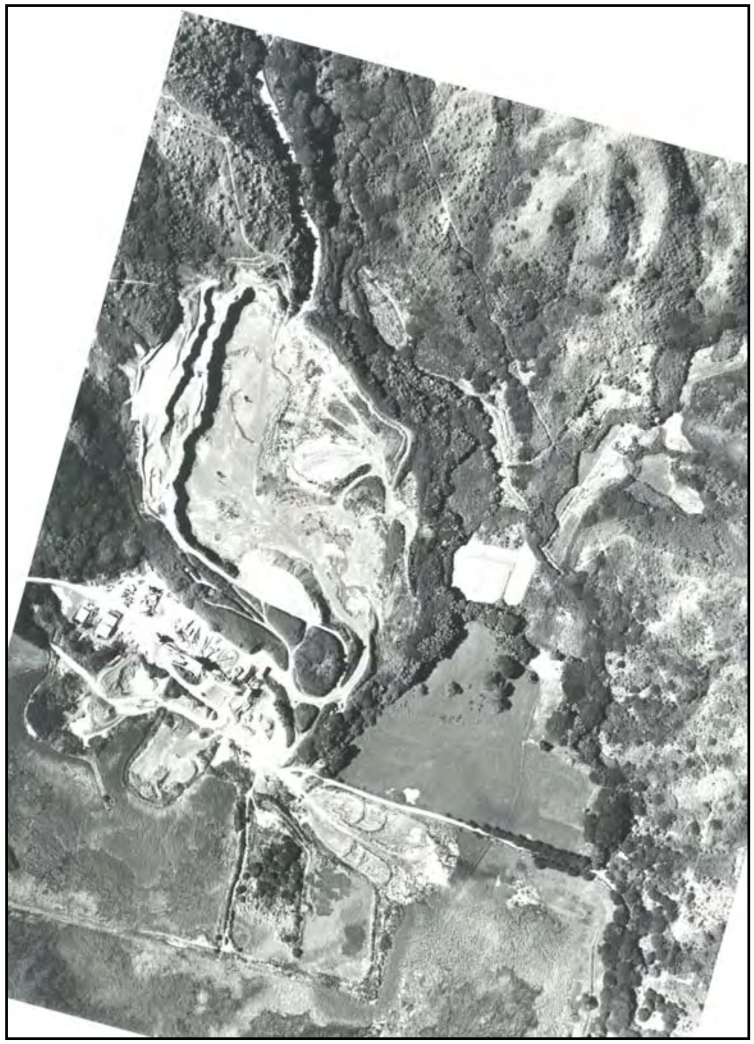


Figure 2-3. 1952 aerial photo of lower Kapa`a valley.

Figure 2-4. 1963 aerial photo of lower Kapa`a valley.



The 1963 photograph shows continued expansion of the quarry resulting in partial fills well out into the Kawainui Marsh (present model airplane field and City & County of Honolulu baseyard). There is no visible change to the course of the stream through the agriculture lots or lower enclosed wetland.

Beginning about 1965, the now fallow agriculture land and enclosed 35-acre wetland area became a refuse dump. Overburden from the quarry was used to cover the refuse. This fill raised the land level an estimated 6 to 20 feet over about 23 of the 35 acres in this lower wetland area. The edge of this fill area is identifiable on the ground as a ridge of exposed waste material. Immediately south of this filled refuse area, overburden from the quarry created a flat 22-acre plateau at an elevation of about 40 feet over the previous agriculture lands and stream channel. This fill pushed the streambed to the northwestern edge of the valley near its present course and isolated the drainage canal along the quarry road from any surface water flow.

In the 1972 photograph construction of the Interstate H3 Freeway is in full progress, filling the eastern side of the Kapa’a streambed. Numerous drainage crossings were made through the foundation of the freeway, ranging from 24-inch drainage culverts to two 10-foot culverts for mainstream channel crossings. The plateau along the central stream reach has been extended an additional 8 or 10 acres towards the freeway increasing the size of this upper plateau to about 33 acres. When the section of freeway through the valley was completed, it created approximately 13 acres (2% of the watershed) of additional impermeable surface.

Figure 2-5. 1972 aerial photo of lower Kapa`a valley.

The Kapa`a watershed is rich in landfills. In 1970 when the Ameron quarry moved its operations across the valley, the City & County of Honolulu opened a controlled Kapa`a landfill within the old quarry excavation. This landfill received about 4.5 million tons of municipal solid waste until its final closure in 1996. The City's Kalaheo landfill, on the east side of Kapa'a Stream and the H3 Freeway, received about 1.3 million tons of waste before its closure in 1990. Since 1992, a green waste recycling company has utilized the top of this landfill to produce mulch and compost.

Light industry entered the Kapa'a valley around 1975, when two warehouse buildings were constructed on the 22-acre quarry-fill plateau in the lower valley. In the late 1990s, a dozen 2000 square foot Quonset huts were constructed on this open, relatively flat area, housing numerous small industry and business operations. All of these features can be seen in the 1999 aerial photograph, Figure 2-6. As of May 2005, the warehouse area includes about 27 structures, 170,000 square feet of leasable space, and 40 tenants, with plans to build another 300,000 square feet as demand dictates (Segal 2005).

Figure 2-6. 1999 aerial photo of lower Kapa`a valley.

The US Army Corps of Engineers constructed a levee across the width of Kawainui Marsh in the 1950s, diverting its historic outlet through Kawainui and Ka'elepulu Streams into a new man-made Oneawa Canal (also known as Kawainui Canal or Kawanui Stream) to the Pacific Ocean. The height of this levee was raised to improve flood control for low-lying portions of residential Kailua after an exceptional flood (36 inches of rainfall in 48 hours) on New Year's Day in 1990.

Through all the upheavals of the Kapa'a valley landscape over the last century, at least one reminder of the earliest Hawaiian history has survived. On the northerly slope of Ulumawao, surrounded by landfills, still stands the 120-foot by 180-foot stone structure of *Pahukini Heiau* (National Register of Historic Places, #72000426). Built by Olopana some 1,500 years ago, this ancient “Temple of Many Drums” silently overlooks the Kapa’a valley and Kawainui Marsh. (It can be seen as the greenish rectangle in the middle of the Kapa’a landfill in Figure 2-6.)

Figure 2-7. *Pahukini Heiau* in Kapa’a watershed, 1991.

2.3 Geology and Landform

The windward side of Oahu is the inner edge of what was the caldera of the massive Koolau volcano. The Kapa’a watershed rests within this ancient caldera. On the southeast side of the watershed, the 995-foot Ulumawao peak separates the Kapa’a valley from the Kawainui Marsh, Pali highway and Maunawili valley. To the northwest, Mahinui Ridge forms the division between Kapa’a and Kawa Stream watersheds (and between the Kailua and Kaneohe *ahupua’a*). These hills are composed of very dense rock formed within the caldera. The rocks are primarily of the Kailua Volcanic Series and are composed of massive basalt flows intruded by numerous vertical dikes (MacDonald 1990). These features are seen in excavation cuts in the Ameron quarry and along the H3 Freeway and Mokapu Saddle Road (Figure 2-8). These rocks have undergone hydrothermal action that has filled voids with secondary minerals, silica and calcite, making these rocks very dense and highly impermeable (Nance 2002). Overlaying this vertically stratified highly impermeable rock, is a layer of breccia, loosely stratified rocks of a variety of types varying in size from a few centimeters to over a meter in diameter (MacDonald 1990). Except for a narrow band of exposed rock along the Ulumawao ridge, Kapa’a valley soils overlying the breccia layer are assigned to NRCS hydrologic soil group B, deep or moderately deep and well drained to moderately well drained soils with a moderate rate of water transmission (NRCS 2001). This relatively permeable surface layer allows infiltration of rainfall and sufficient time for percolation into the less permeable dense rock below. The result is that vertical dikes within the hills contain fresh ground water reserves that slowly feed Kapa`a Stream and adjacent surface waters.

A recent investigation (Nance 2002) found the ground water elevation in the Ameron quarry pit on the northwest side of the H3 freeway at about 120 feet, or just below the quarry surface, and that infiltration from the surrounding basalt is at a very slow rate of about 5 gpm. Nance estimated that prior to quarry operations the water level in the dike system was probably at about 160 feet elevation. During excavations for its landfill operations, the City and County of Honolulu released copious amounts of groundwater from the surrounding rock (CCH 2004).

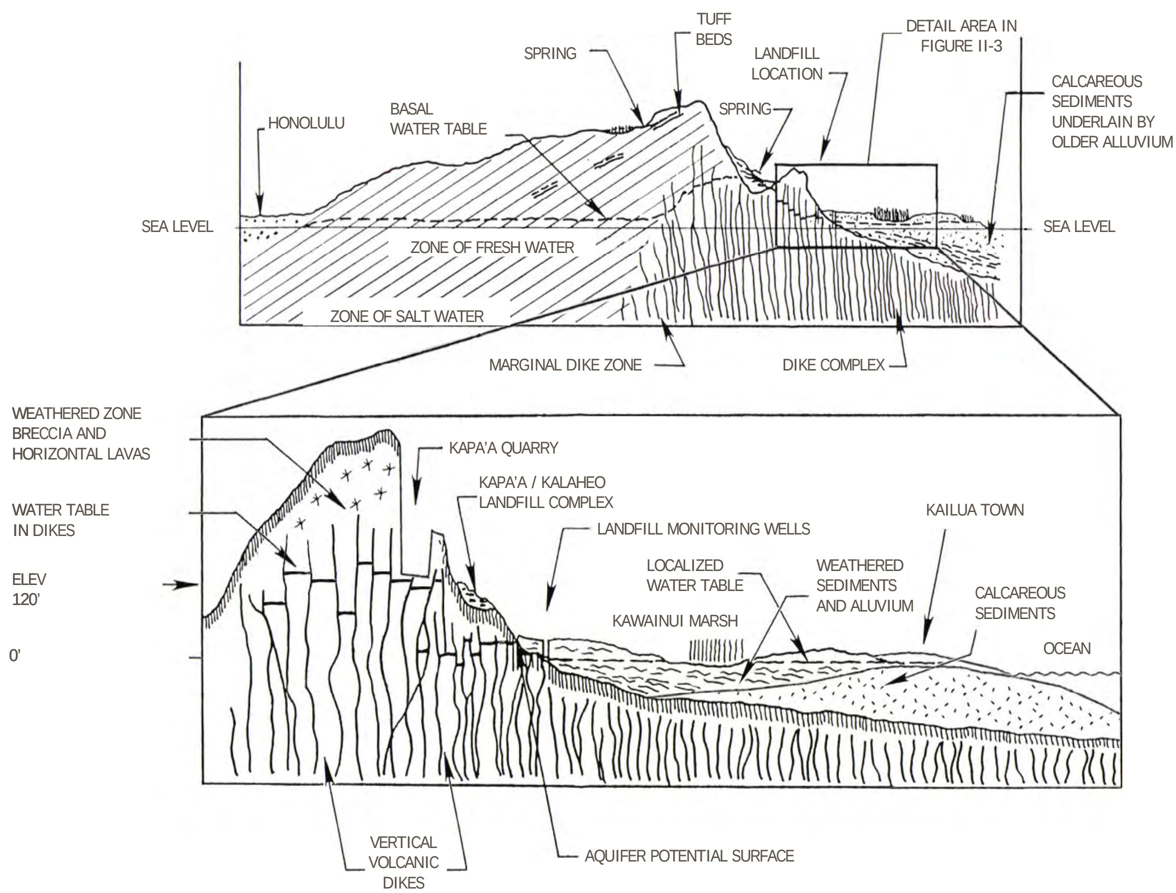


Figure 2-8. Windward Oahu geology schematic.

The geology schematic shows the high water table in dense vertically stratified dike structures beneath the quarry and landfill areas, with transition to porous alluvial sediments in the lower valley.

2.4 Climate

Rainfall in the Kapa’a watershed is primarily from local tradewind showers or large weather systems over the entire island. These latter are island-wide storm fronts associated with North Pacific lows, subtropical Kona storms (about one per year), or hurricanes (about one in 10 years). The orographic lift that provides most of the rainfall along the steep windward side of the Ko’olau range is not much of a factor because the Kapa’a hills are not sufficiently high and their location about 3 miles from the central island ridge is beyond the effect of typical orographically- induced showers.

Oahu on average receives about fifteen North Pacific frontal systems per year, of which four to eight produce an average of one to five inches of rain over a 1 to 3 day period. The majority of rainfall events in the Kapa`a watershed are non-thermally induced tradewind showers. These showers tend to be most frequent in the morning and evening and are often intense, but have short duration and are spatially limited. A typical trade wind rain shower might have a diameter of 1 or 2 miles and be moving with the trade winds at 5 to 15 mph. From the perspective of a fixed point on land, the storm duration will be 4 to 20 minutes during which 0.1 to 0.5 inches of rain may fall (Oceanit 2002).

The climatic statistical model known as PRISM (parameter–elevation regressions on independent slopes model) developed at Oregon State University for USDA-NRCS and other agencies (Daly et al, 2002) has recently been extended by NRCS to all of the U.S. states including the islands of Hawaii. The PRISM system provides 30-year (1961-1990) statistical regressions of annual and mean monthly rainfall distributions at 500m x 500m grid cell resolution for Oahu, including the Kapa’a watershed area. Seasonal distributions were obtained from summations of May-October (dry season) and November-April (wet season) monthly rainfall values. PRISM seasonal rainfall grids are overlaid on the Kapa’a watershed area in Figures 2-10 and 2-11 (rainfall in mm).

Data from the weather station at Pali Golf Course, adjacent to the southern boundary of the Kapa’a watershed, provides a record of daily rainfall for the 30-year period of the PRISM statistical regressions. With the assumption that temporal rainfall distributions are similar across small watershed areas, then spatial distributions of rainfall for an individual event, e.g., 10% or 2% frequency storm, can be approximated from the PRISM seasonal distributions and the individual event data from a single reference monitoring station (Technical Appendix, Section A.2.0). For the 30-year Pali Golf Course record, rainfall was equal to or greater than 0.35-inch during 10% of the dry season days and equal to or greater than 0.70-inch during 10% of the wet season days. Rainfall was equal to or greater than 1.27-inch during 2% of the dry season days and equal to or greater than 2.30-inch during 2% of the wet season days. These rainfall statistics and the PRISM distributions provided the basis for approximations of Kapa’a watershed hydrology and pollutant load distributions.

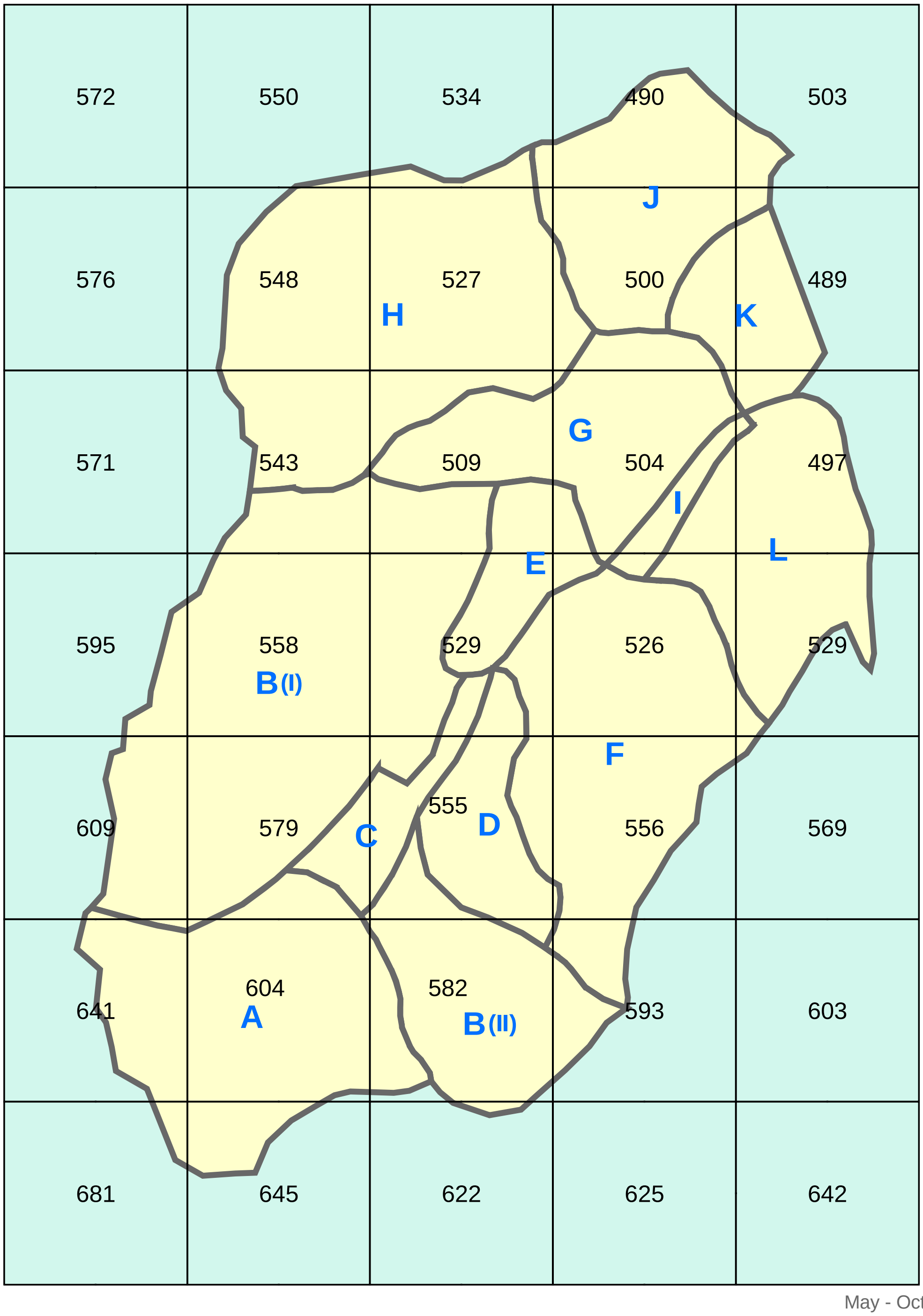


Figure 2-9. PRISM dry season rainfall distribution (mm) for Kapa'a watershed.

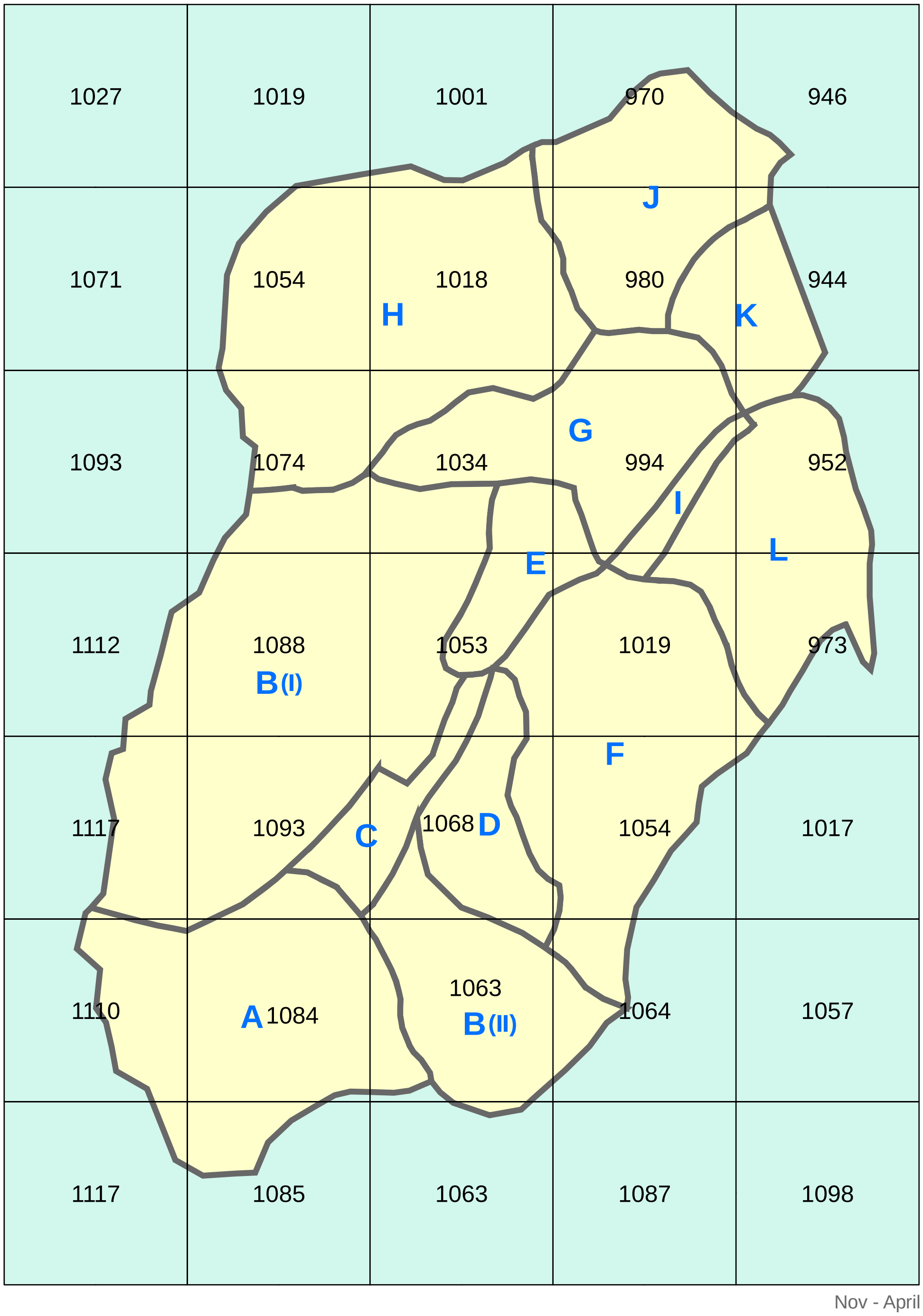


Figure 2-10. PRISM wet season rainfall distribution (mm) for Kapa'a watershed.

Chapter 3
Source Descriptions

3.1 Stream Segments

Kapa'a Stream is segmented in this report according to watershed drainage pattern (topography), land use/land cover, and available sampling data locations. Sampling stations are those described in the previously reported Kapa'a stream survey (Oceanit 2002). The six stream segments and associated tributary drainage area boundaries displayed in Figure 3-6 are described further below.

Segment 1: Headwaters Reach. Kapa`a Stream arises in a steep gulch on the southwest slope of Ulumawao. Segment 1 extends from the headwaters origin about 3,600 feet downstream to the primary discharge location for the Ameron Quarry sediment pond complex. Midway along this segment, the stream crosses through a culvert from the southeast to the northwest side of the H-3 highway, where it continues downstream parallel and adjacent to this highway.

Segment 2: Upper Quarry Reach. Segment 2 extends from the primary Ameron Quarry outfall location 2,000 feet downstream to the main Ameron entrance gate at the quarry access road. The downstream end of this segment is the upstream entry of a 10-foot culvert that carries the stream beneath the quarry access road as this road forks toward the Kalaheo landfill and greenwaste facility.

Figure 3-1. Kapa'a stream channel downstream from Ameron Quarry outfall in Segment 2.

Segment 3: Lower Quarry Reach.   This segment begins at the 10-foot culvert beneath the access road at the main Ameron entrance gate and extends about 1,800 feet downstream to a location where runoff from the Kapa'a landfill enters the stream through a concrete energy-dissipation chute. From the culvert beneath the Kalaheo landfill access road, Kapa'a Stream falls to small plunge pool. Water is perennially present from here to the stream's confluence with the Kawainui Marsh. At about one-third of the distance along segment 3, the stream returns through a culvert from the northwest to the southeast side of the H-3 highway. It continues thereafter generally parallel to and southeast of the highway.

Figure 3-2. Plunge pool downstream from the beginning of Kapa'a Stream Segment 3.

Segment 4: Kapa'a Middle Reach.   Segment 4 begins at the discharge location of the Kapa'a landfill energy-dissipation chute and extends about 1,400 feet downstream to a small pond and gravel berm that crosses the valley floor. Just upstream from this gravel berm, sediment pond overflows from the Kalaheo landfill runoff enter the stream.

Segment 5: Canal.   The canal segment lies along the western side of Kapa'a Quarry Road between the intersection with the quarry access road and the confluence point 1,200 feet to the northwest where Kapa'a Stream flows through a culvert beneath Kapa'a Quarry Road into the Kawainui Marsh.

Figure 3-3. Small pond and gravel berm at the end of Kapa'a Stream Segment 4.

Figure 3-4. Canal (Segment 5) upstream from its confluence with Kapa'a Stream Segment 6 (in foreground).

Segment 6: Kapa'a Lower Reach. Segment 6 begins at the gravel berm at the end of segment 4. Runoff from the lower part of the quarry access road enter Kapa'a Stream at this location. From this point the segment extends 1,500 feet downstream to its confluence with the canal segment 5 and the culvert beneath Kapa'a Quarry Road through which the stream flows into Kawainui Marsh.

Segment 7: Marsh Inflow. This segment is the combined flow from Kapa'a Stream segments 5 and 6 that flows into the marsh.

Figure 3-5. Kapa'a Stream as it flows beneath Kapa'a Quarry Road and into Kawainui Marsh (Segment 7).

Segment 8: Marsh Inflow. This segment is the overflow to Kawainui Marsh from the sediment pond that collects and retains the storm runoff from Sub-basin L (City & County of Honolulu Waste Transfer Station and Corporation Baseyard).

3.2 Watershed Sub-basin and Source Descriptions

Watershed sub-basin boundaries are determined from topography and constructed drainage modifications that have substantially altered the original paths of surface water and groundwater flows. For the most part, except in the uppermost headwaters area, the historical stream channel no longer exists. Figure 3-6 displays the boundaries of the 12 sub-basins. These boundaries are overlaid on infrared (IR) imagery of the Kapa'a watershed area from the 1999 IR mosaic by the Cartography Laboratory, University of Hawaii (original photography by Air Survey Hawaii for DLNR, 1991-93).

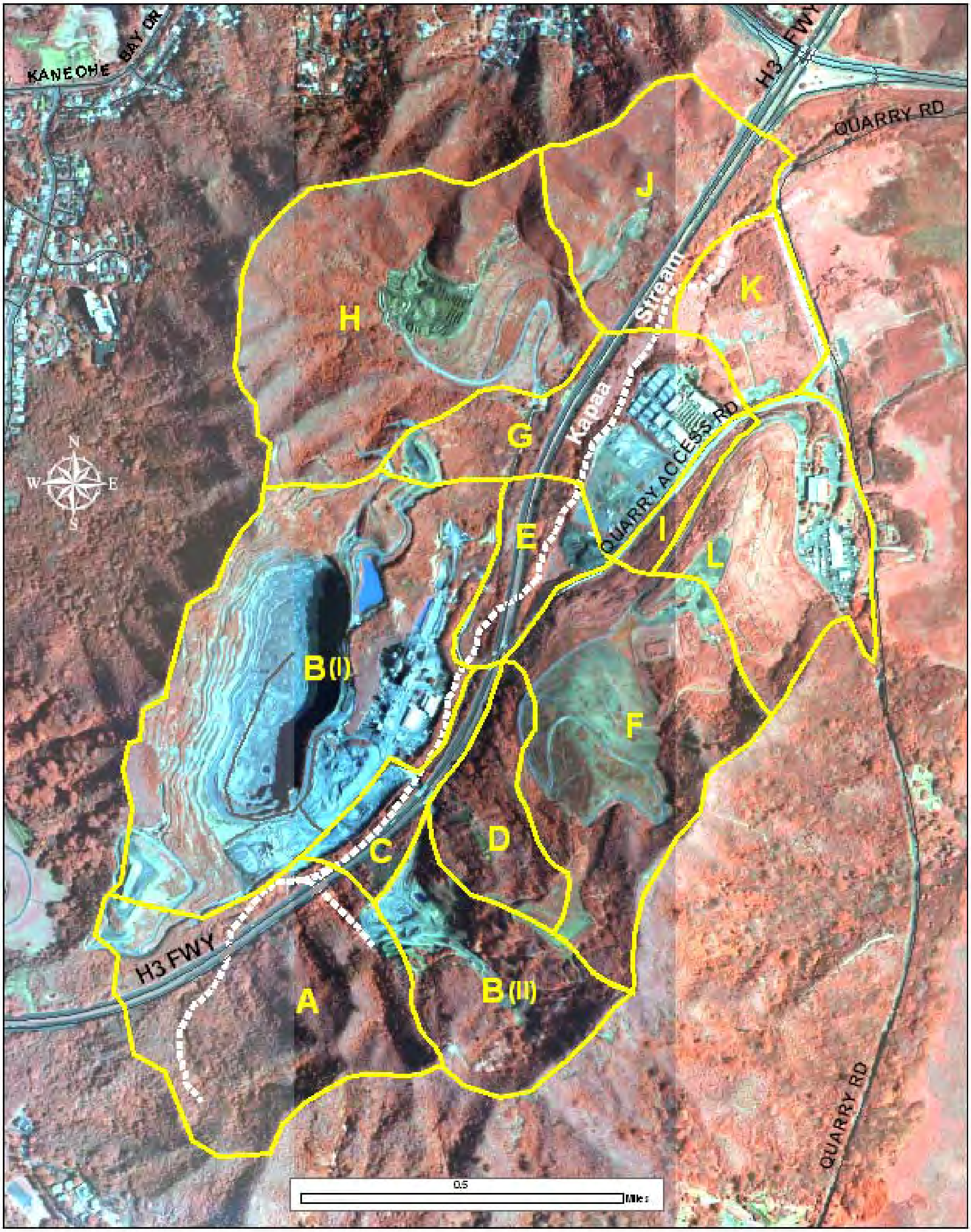


Figure 3-6. Aerial photograph of Kapa'a watershed and superimposed sub-basin boundaries.

The following descriptions of the tributary drainage areas of the Kapa'a watershed summarize the land use, land cover, human activity, and drainage conditions reported in the Kapa'a stream survey (Oceanit 2002).

Sub-basin A: Headwaters.

The 96-acre headwaters area provides the tributary drainage for stream segment 1. The area is covered with a mesic scrub forest consisting primarily of octopus tree (*Schefflera actinophylla*). Slopes are generally steep, averaging 11 percent above both sides of the H-3 highway that traverses this area. The bottom of the streambed ravine and slopes close to the highway support a variety of trees, primarily java plum (*Syzygium cumini*), Christmasberry (*Schinus terebinthefolius*), fiddlewood (*Citharexylum caudatum*), monkeypod (*Samanea saman*), and, in the lowest areas, hau (*Hibiscus tiliaceus*). Some albizia (*Paraserianthes falcataria*) and African tulip (*Spathodea campanulata*) trees are present, as well as scattered ironwood (*Casuarina equisetifolia*). Only minimal bare soil slopes exist since cuts created when the highway was constructed have long since overgrown with trees and grasses. The lowermost portion of this sub-basin is a steeply ravined slope on the southeast side of the H-3 highway that is covered primarily by non-native mesic scrub (mostly octopus trees). A drainage culvert under the highway connects this area to Kapa`a Stream near the top of Sub-basin C.

Figure 3-7. View across H-3 Highway to lower slopes of Ulumawao and Kapa'a Stream headwaters in Sub-basin A.

Sub-basin B: Ameron Quarry.

Ameron quarry operations occupy both sides of upper Kapa`a Valley. Two phases of the quarry operations are separated by Kapa'a Stream and the H-3 highway. The Phase II operation on the southeast side of the highway covers about 35 acres. Runoff from surrounding up-gradient forested lands and the active quarry area is controlled on site through a system of drainage swales, holding basins, sumps, and pumps. Runoff captured by this system is pumped across

Kapa'a Stream and the H-3 highway to the stormwater recycling system in the Phase I quarry. The more long standing Phase I quarry operation on the northwest side of the highway occupies about 150 acres, from which an estimated 40 million tons of rock have been removed since 1972 (Oceanit 2002). An interconnected system of sedimentation and storage ponds in the Phase I quarry retains runoff stormwater for recycling in dust control, irrigation, and plant process operations. Runoff water exceeding the volume of this system is drained into the Phase I quarry pit. The stormwater recycling system for the quarry operations is diagrammed in Figure 3-10. This system is designed to contain the quarry area runoff from a 10-inch, 24-hour rainfall event.

Figure 3-8. Aerial view of Ameron Quarry (Phase I) on the southwest side of the H-3 Highway. Kapa'a Stream lies in the narrow vegetated strip between the quarry and the H-3.

Figure 3-9. Bottom of the Ameron Quarry (Phase I). Excess storm runoff from sediment retention ponds in the quarry area is drained to the pond in this quarry pit.

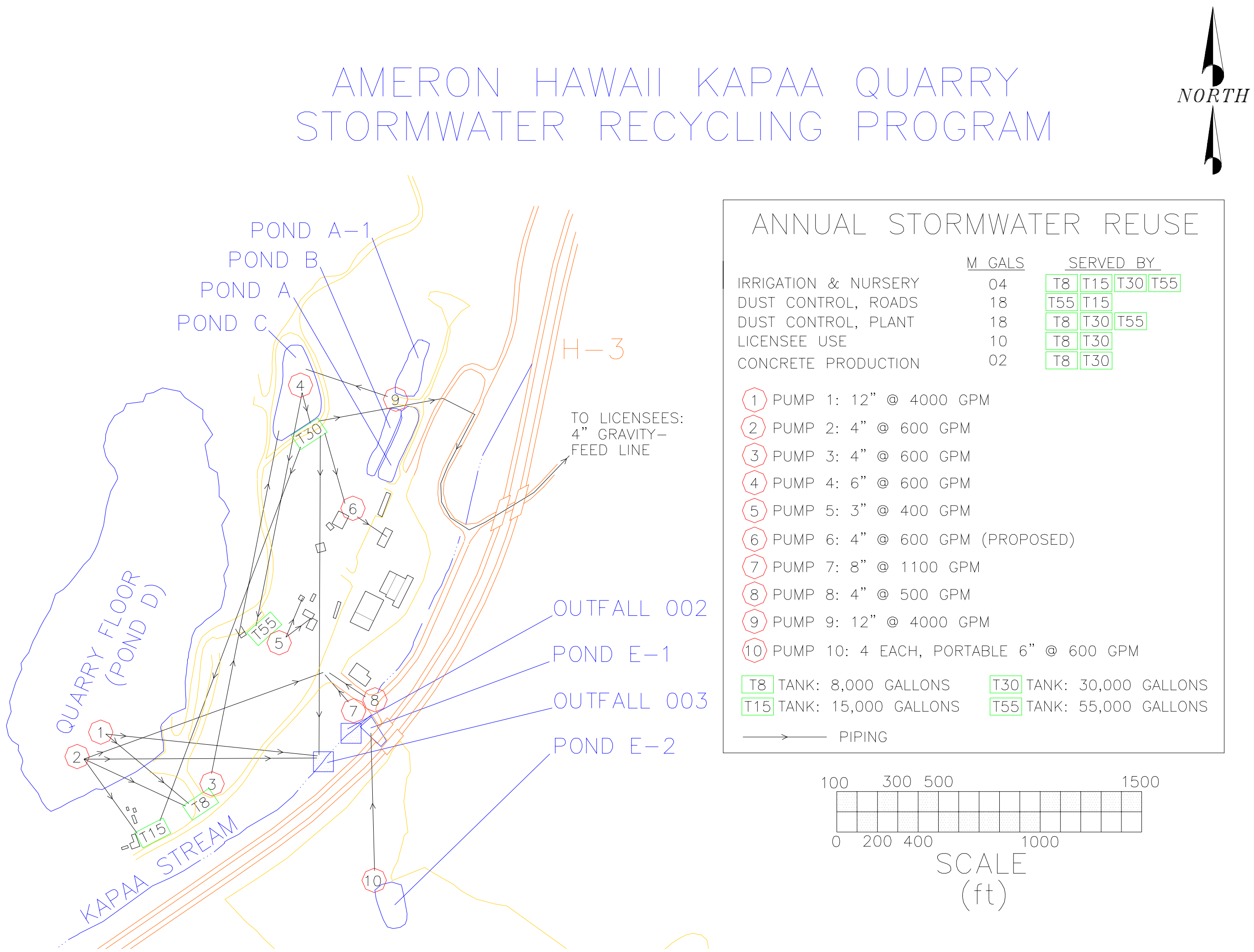


Figure 3-10. Ameron Quarry storm runoff retention and recycle system schematic.

A graveled road along the southern border of the Phase I quarry operation provides access from the quarry operations area to the hills and cliff face overlooking the quarry pit. The road is graded to intercept runoff from quarry operations (in this area, mostly overburden storage) during heavy rains, so all land above the road drains back into the quarry operations area along road surface and drainage ditches. During the 2002 Survey, the gravel road was found deeply eroded and stormwater flows had broken through a berm separating it from the adjacent Kapa`a Stream (Figure 3-11). This was possibly the source of much of the gravel found in the streambed during the first several storm events. With subsequent repair, the road is now reported to channel all runoff into the Ameron stormwater recycling system (Figure 3-12).

During the winter of 2002, drainage from the stockpile, catchment pond, and access road area along the northerly boundary of the Phase I quarry operation was found flowing down the access road and into Kapa'a Stream through drainage culverts beneath the road. In March 2002, Ameron constructed an infiltration basin near the base of the road and runoff flows from this area were not subsequently observed (Oceanit 2002).

Figure 3-11. Erosion of closed access road above upper quarry.

Figure 3-12. Repair and berming of access road in June 2002.

<u>Sub-basin C: Upper Ameron Reach</u>.

This narrow 17-acre sub-basin is the immediate tributary drainage area for Kapa'a Stream segment 2. It largely consists of the right-of-way for the H-3 highway between the Ameron Phase I and Phase II quarry operations. The Kapa'a streambed in this area is deeply incised between the Phase I quarry and the highway, with bank plantings of *Erythrina* trees maintained by Ameron as a screen between the quarry and the freeway (Figure 3-1). Midway in sub-basin C, where Kapa`a Stream flows through a culvert under the access road between Ameron's Phase I and Phase II operations (WQ Station 6), runoff from the H-3 highway is discharged to the stream from drainage culverts. From this point to the bottom of the sub-basin at Ameron's main gate, the streambed and much of the banks have been stabilized over the years with concrete pours. Another 24-inch culvert at the Ameron Gate discharges additional runoff from the H-3 and its adjacent drainage area. This highway drainage is often red tinged by sediment eroding from the slopes of Sub-basin D above the highway where off-road vehicles have created trails all over the hillside.

<u>Sub-basin D: Kapa`a Landfill Phase-III Eroded Forest Area</u>.
Sub-basin D is a 29-acre steeply sloped area owned by Kaneohe Ranch and draining toward the H-3 highway. Runoff from this area and the highway is discharged through a 24-inch culvert to the end of Kapa'a Stream segment 2 at the Ameron Quarry entrance gate. Vegetative cover is largely introduced koa-haole (*Leucaena leucocephala*) and Guinea grass (*Panicum maximum*). In the uppermost part of the area, near the summit of Ulumawao, there are patches of native forest consisting of a scrub form of `ohi`a lehua (*Metrosideros polymorpha*) and an abundance of `akia (*Wikstroemia* cf. *oahuensis*). Much of this sub-basin area has been a regular site for off-road vehicular recreation that has caused severe soil erosion.

Figure 3-13. Eroded area in Sub-basin D above H-3 Highway.

Figure 3-14. Discharge of red sediment from eroded Sub-basin D through the H-3 Highway drainage system.

<u>Sub-basin E: Upper Valley Bottom</u>.

This 24-acre sub-basin is the immediate tributary drainage area for Kapa'a Stream segment 3. It is bisected by the H-3 highway. Kapa'a Stream crosses beneath the highway from northwest to the southeast in the middle of this sub-basin. The sub-basin begins just downstream from the main Ameron entrance gate, at the lower end of the 10-foot culvert beneath the access road to the Kalaheo landfill area. A small spring-fed flow at this point was estimated at approximately one liter/minute in late summer (Oceanit 2002). Stream elevation at this spring is about 115 feet, slightly below the 120-foot water table measured at the bottom of the quarry pit (Nance 2002). A small plunge pool about 30 feet downstream is home to prawns (*Macrobrachium lar*) and an unidentified poecilid fish (Figure 3-2). Thick vegetation covers the sub-basin on both sides of the H-3 highway. Coarse sand and gravel cover the bottom of the culvert beneath H-3 and the stream channel just downstream. The sub-basin extends downstream to the concrete energy dissipation chute where the runoff from Sub-basin F (Kapa'a landfill) is discharged to the stream.

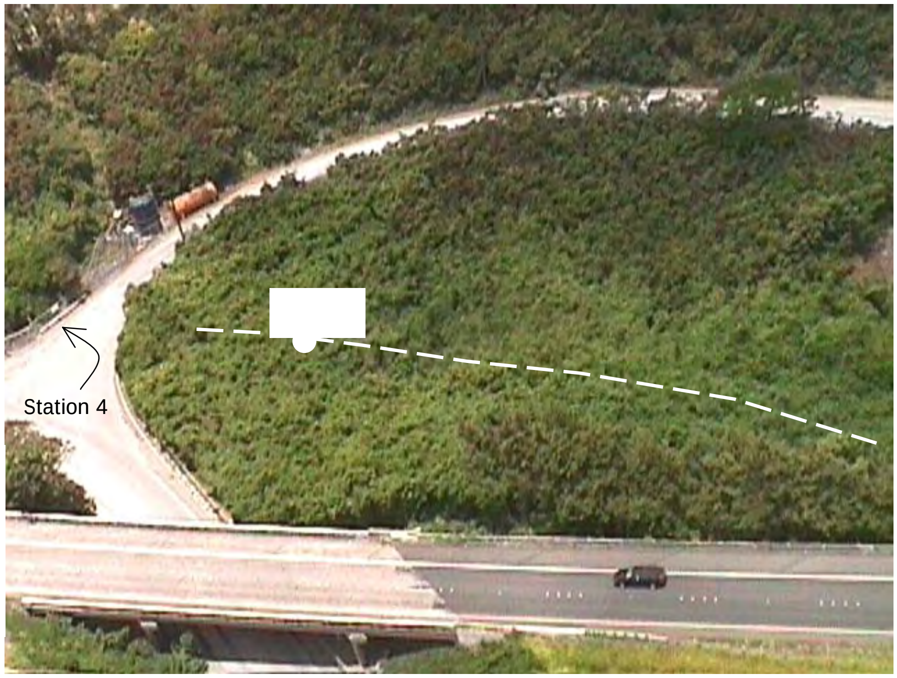


Figure 3-15. Upper portion of Sub-basin E, showing path of stream channel and plunge pool location.

<u>Sub-basin F: Kapa'a Landfill, Phase-II</u>

The 98-acre area of this sub-basin contains both the upper part of the City & County of Honolulu Kapa'a Landfill (Phase II) and relatively undisturbed slopes up to the ridgeline of Ulumawao at about 600-foot elevation. Natural terrain at the Ulumawao summit is steep and slopes are variable in the landfill area of constructed fills and terraces. Vegetative cover on the landfill cap consists primarily of Guinea grass and other seeded grasses. Less disturbed slopes are dominated by Java plum and monkeypod trees. At the ridgeline there are patches of native plants such as *`ulei* (*Osteomeles anthyllidifolia*), *`ilima* (*Sida fallax*), and *`akia*. Historical references describe a spring in this sub-basin, but no surface expression of this spring was found in 2002. The historic *Pahukini heiau* is located on a slope surrounded by the landfill in this area.

Runoff from this sub-basin is collected in a circumferential drainage swale constructed around the upper landfill and transported downslope to a 48-inch culvert that passes under the quarry access road and discharges down a concrete energy-dissipation chute at the head of Sub-basin G (Figure 3-17). A desilting basin was originally constructed at the base of this energy-dissipation chute but this basin has been nearly or completely filled with sediment since about 1995 (Oceanit 2002). This was the observed condition in 2005 (DOH 2005). Some of the material filling the sediment basin may not be from landfill runoff but appears to have been spread in from the direction of an adjacent asphalt recycling operation. Aerial photos suggest that the footprint of this asphalt recycling operation has expanded in recent years to encroach into the original sediment basin area.

Figure 3-16. Runoff from the Kapa'a Landfill is captured by rock-lined swales and transported by a buried conduit to the energy dissipation structure that empties at the head of Kapa'a Stream Segment 4 through Sub-basin G.

Figure 3-17. Runoff from the Kapa'a Landfill empties down this energy dissipation chute into Kapa'a Stream. Filled-in area in foreground was once a desilting basin.

Sub-basin G: Valley Bottom.
This sub-basin is the immediate tributary drainage area for Kapa'a Stream segment 4. The area is about 60 acres on both sides of the H-3 highway and Kapa'a Stream. The western side of this sub-basin lies above the H-3 highway and drains through several 24 to 36-inch culverts beneath the highway and Kalaheo landfill access road to the densely foliated bed of Kapa`a Stream below Sub-basin E. Slopes of the Mahinui ridge above the highway are relatively steep (24 percent) and covered with dry land scrub, dominated by koa-haole. The eastern side of the sub-basin is mostly a plateau constructed between 1962 and 1972 of tailings and overburden from the adjacent original Kapa`a quarry operation. Geological boring in this area did not show any evidence of trash under this fill (Lum 1983). In 1965 the plateau area was about 22 acres but by 1972 this had been expanded by unknown sources to 35 acres. This entire area is leased from

Kaneohe Ranch by John T. King and sub-leased to light industry tenants. Approximately 10 of the 35 acres are occupied by a small business complex consisting of over two dozen Quonset huts, two large warehouses, and miscellaneous outbuildings. There is little vegetation on the flat surface of the plateau. Percolation of rainwater into the fill appears to be rapid except where surfaces have been paved or compacted. Runoff from these paved surfaces, particularly in the light industrial area, flows over the edge of the plateau at multiple locations to Kapa'a Stream.

Figure 3-18. Overlook of Sub-basin G and light industrial facilities on level area created by fill material from the original quarry operation at the present Kapa'a Landfill site.

The Kapa'a streambed is narrowed between the footing of the H-3 highway and the quarry-fill plateau supporting the light industrial area. Foliage is extremely thick in this segment of the stream and the area was not accessed on foot. The stream drops in this area through dense stands of giant elephant grass for about a quarter mile. Near the downstream end of the sub-basin, overflow from the Kalaheo landfill sediment pond enters Kapa'a Stream through an 8-foot culvert beneath the H-3 highway. Approximately 500 feet further downstream, in a dense stand of elephant grass, a permanent pond at a gravel berm marks the junction between sub-basins G and J, and stream segments 4 and 6, (Figure 3-4). At this point the streambed elevation is about 24 feet.

<u>Sub-basin H: Kalaheo Landfill</u>.

This 126-acre sub-basin contains the City & County of Honolulu Kalaheo landfill. This is an unlined landfill that received municipal solid waste for about three years during the 1990's and presently houses a green-waste recycling facility. The actual landfill area is only about 30 acres which, along with the surrounding scrub-covered 93 acres up to the Mahinui ridge summit, all drain into the landfill runoff collection system. This system consists of two main conduits, one on either side of the landfill, with cross branches at each landfill terrace. The main branches meet below the bottom of the landfill in a 100-foot by 200-foot, five to eight feet deep, sediment basin. Overflows from this basin pass through an 8-foot culvert beneath the H-3 highway and into Kapa'a Stream at the bottom of sub-basin G (end of stream segment 4). During the 2002 biological survey, this sediment basin was observed to overflow significantly only once (May 2002 rainfall event).

Figure 3-19. Kalaheo Landfill looking upslope from access road. Drainage channel passes under road in center of photo.

Figure 3-20. 100’ x 200’ sediment retention basin at the base of Kalaheo Landfill in Sub-basin H.

Sub-basin I: Lower Quarry Access Road.

This narrow 8-acre sub-basin consists of the Kapa'a landfill slope below the landfill access road down to and including the lower portion of the Ameron quarry access road. Runoff from this area is carried in a drainage swale along the south side of the access road to the northern edge of sub-basin G. At this point, the runoff flows through a culvert beneath the access road to a percolation field between sub-basins G and K before it enters Kapa'a Stream at the beginning of stream segment 6.

Sub-basin J: Kapa`a Stream Mouth.

This 59-acre sub-basin is the furthest downstream area of the Kapa'a watershed and contains the mouth of the stream where it flows into Kawainui Marsh (Figure 3-5) at an elevation of about 5 feet. The sub-basin is traversed from south to north by the H-3 highway. Upland slopes above H-3 are part of the Mahinui ridge and are covered by a scrub growth of koa-haole, and aggressive fiddlewood (*Citharexylum caudatum*) gradually covering significant areas of the hillside. Three culverts (42-inch, 42-inch and 30-inch) beneath the H-3 highway connect this upland area to the Kapa'a streambed. Headwalls of these culverts are hidden within dense hau growth along the base of the highway fill. At the boundary between sub-basins G and J, a gravel berm once served as a roadbed across the valley bottom wetland. This berm was intact until 1995 when a channel was opened to allow free flow of water. The channel opening created a small pond on Kapa`a Stream (Figure 3-3). The old gravel roadbed forces the stream flow to the highway side of the valley where the stream meanders in channels partly within a dense growth of hau (*Hibiscus tiliaceus*) and through adjacent fields of elephant grass (*Pennisetum purpureum*). The lower reach of Kapa'a Stream, from the gravel roadbed berm to Kapa`a Quarry Road, flows through a much-disturbed wetland marked by pockets of umbrella sedge.

Figure 3-21. Wetland area of Sub-basin J.

Sub-basin K: Green-Waste Recycle Site.

This sub-basin is about 28 acres of low, nearly level quarry-spoil landfill that covers residential waste dumped into the wetland between 1965 and 1972. The surface of this area is covered with Guinea grass and koa-haole shrub and the remnants of previous construction storage and solid refuse. Larger trees grow on the boundary of the old landfill area along Kapa'a Stream. Some of the site is being developed as a green-waste recycling facility. A canal (Stream segment 5) separating this sub-basin area from Kapa`a Quarry Road usually appears stagnant, receiving little surface water inflow during rainfall events. However, groundwater weeping from the side of the landfill into the canal has been observed and sampled (Oceanit 2002).

Sub-basin L: Lower Phase I Kapa'a Landfill.

This 62-acre sub-basin contains the lower Phase I part of the Kapa`a landfill. This section of the landfill occupies the site of the first Ameron quarry operated between 1949 and 1964 that was subsequently employed by the City and County of Honolulu for landfill disposal of municipal solid waste. Closure of this landfill included construction of a surface water drainage swale along the upslope side of the landfill access road. This drainage swale intercepts and directs storm runoff around the western and northerly slope of the landfill to a sediment pond adjacent to Kapa'a Quarry Road. This sub-basin also includes the C&CH refuse transfer facility and runoff from this facility flows also to the landfill sediment pond. Overflow from the sediment pond flows through a culvert beneath Kapa'a Quarry Road and into Kawainui Marsh.

Figure 3-22. Drainage swale along lower Kapa`a landfill access road directs runoff to a sediment retention pond behind the refuse transfer facility and into Kawainui Marsh.

Chapter 4
Water Quality Data

4.1 Oceanit Survey

In 2001-02, Oceanit Laboratories conducted a water quality survey of Kapa'a Stream on behalf of Ameron, Hawaii, the operator of Kapa'a Quarry (Oceanit 2002). The limited amount of surface water and groundwater data available from previous studies are summarized in the 2002 Survey report. Sampling stations for the Oceanit survey and their locations relative to the stream segments in this TMDL analysis are as follows.

Station 7. This sampling location is at the boundary between stream segments 1 and 2. Samples are from the Kapa'a Stream channel. Drainage at this point is entirely from Sub-basin A.

Station 6. This location is about midway in stream segment 2, at the access road crossing between the Phase I and Phase II Ameron quarry operations. Data from this station reflect stormwater discharges from the H-3 highway above the access road and from the Ameron stormwater retention and recycle system.

Station 5. This station is located at the inflow to the Kalaheo landfill sediment pond. Samples from this station are of storm runoff from the landfill and Sub-basin H.

Station 4. This location is at the boundary between stream segments 2 and 3. Samples are from the Kapa'a Stream channel. Data from this station reflect additional drainage from Sub-basin D and the H-3 highway in the lower portion of Sub-basin C.

Station 3. Station 3 is located at the upstream side of the energy-dissipation chute in Sub-basin F. Samples from this station are of storm runoff from the upper Kapa'a landfill area and Sub-basin F.

Station 3a. This instream station is located at the approximate boundary between stream segments 4 and 6. Samples are from the Kapa'a Stream channel.

Station 2. Station 2 is located at the upstream end of the segment 5 canal alongside the Kapa'a Quarry Road.

Station 1. Station 1 is located at the mouth of Kapa'a Stream where it flows beneath Kapa'a Quarry Road into the Kawainui Marsh.

4.2 Survey Data

Aquatic habitat conditions in 2002 were described in the Oceanit survey report:

Qualitative observations of stream habitat made during the performance of other tasks within (the) survey indicate that the habitat value of the stream is limited. The stream is perennial but discontinuous from an elevation of about 115 feet down to the base of the stream at about 5 feet elevation, a distance of less than one mile. A plunge pool at elevation of about 100 feet provides year round habitat to freshwater prawns (*Macrobrachium lar*), toads (*Bufo marina*) and at least one Poecilid unidentified fish. The next known permanent pool of water is at an elevation of about 18 feet adjacent to a gravel bar. The coffee to pea-green colored water of this pool emerges from and re-enters a thicket of elephant grass and undoubtedly harbors aquatic fauna other than the observed mosquito fish (*Gambusa affinis*). At the base of the stream tilapia are present but hidden by a mat of floating vegetation including water hyacinth, giant salvinia fern, and water lilies.

Previous studies of avifaunal and feral mammal populations (Bruner 1994), and botanical resources (Char 1994) have been conducted in the lower 70 acres of the valley. These studies conclude, in general, that the habitat is largely disturbed, non-native, and in its present form provides minimal habitat for native Hawaiian, endangered, or environmentally sensitive species.

The avifaunal survey identified 14 species of exotic birds, one species of migratory bird (two Pacific Golden Plovers, *Pluvialis fulva*) two Black-necked Stilts (Ae`o, *Himantopus mexicanus knudseni*, endangered), a Black-crowned Night Heron (Auku`u, *Nycticorax nycticorax*, native non-endangered), and a pair of Hawaiian Ducks (Koloa, *Anas wyvilliana*, endangered) from this site. It is also likely that Hawaiian Coots, and Moorhens (both endangered species) also use this site on occasion for foraging. The abundance of predators (primarily mongoose and feral cats) and paucity of open wetland habitat render this watershed of limited value for wetland birds.

The botanical survey (Char 1994) indicates that the vegetation on the project site consists almost exclusively of introduced or alien plants. Only 4 of the 135 species inventoried on the property are of Polynesian introduction, and only 8 are native Hawaiian species. No endemic or any listed, proposed, or candidate endangered species were noted on the property. Wetland areas, approximately 12 acres, were identified in the lower portion of the property immediately adjacent to the stream. Additional surveys (Guinther AECOS unpublished observations, 2002) indicate the presence of relatively undisturbed native Hawaiian forest habitat including ‘ohi‘a, ‘akia, and ilima on the ridges and summit of Ulumawao at the upper southern edge of the valley.

The Oceanit survey collected data during both dry weather and storm event conditions. The dry weather data are summarized below in Table 4.1.

Table 4.1. Kapa’a Stream Baseline Dry Weather Water Quality Data

Kapa'a Baseline: Non-rainfall Data

Sample Date	Time	Station	TSS (mg/l)	Turb. (NTU)	TN (µg/l)	TP (µg/l)	Comment
02/04/95		1		41.8	1600	42	Oceanit '95 Study
04/17/95		1	25.8		1480	357	Oceanit '95 Study
11/26/01	0:00	1	132	108	5290	871	No flow at sampler site
03/30/02	8:30	1	16.3	36.3	5830	155	Baseline
04/04/02	6:00	1	14.3	15.7	7500	105	Baseline sample, Oil sheen on surface
05/03/02	10:00	1	36	46.8	723	250	All samples look same
05/03/02	12:00	1	8.8	26.1	1410	180	All samples look same
05/03/02	16:00	1	11	34.2	---	---	All samples look same
05/03/02	20:00	1	11.3	36	1620	220	All samples look same
05/04/02	0:01	1	10.7	33	---	---	All samples look same
05/04/02	4:00	1	10.3	35.6	---	---	All samples look same
05/04/02	8:00	1	14.7	45.4	1580	250	All samples look same
07/01/02	7:00	1	55.7	76.1	5060	350	Baseline
10/04/02	0:00	1	0	0	2150	310	Kapa`a Base - baseline
11/26/01	0:00	2	21	32.3	30900	263	No flow at road crossing
05/07/02	9:30	2	164	234	4040	700	site 2 baseline
05/07/02	9:35	2a	19	69.4	16100	150	Landfill weep w oily film from tire rut
10/04/02	0:00	3a			379	60	Gravel berm pond
02/04/95		4		42.6	12000	113	Oceanit '95 Study
02/25/95		4	11		15300	164	Oceanit '95 Study
04/17/95		4	13.4		1920	79	Oceanit '95 Study
05/05/02	14:20	4c	1.2	1.6	1830	140	Spring at low end of 10' culvert
10/04/02	0:00	4c			3030	90	Kapa`a Spring

Wet weather water quality data are summarized below in Table 4.2. Conditions experienced during the 2001-2002 survey period included erosion of some quarry access roads and drainage systems, failure of an earthen storm runoff retention berm, and resulting bypasses of Ameron’s stormwater recycle system. Also apparent were failures in the Kapa’a landfill cover leading to excessive soil erosion losses in Sub-basin F. These conditions have since been largely repaired, so peak wet weather concentrations of suspended solids, nitrogen, and phosphorus are assumed to be less today than those reported from 2001 and early 2002.

Table 4.2. Kapa'a Stream Wet Weather Water Quality Data

Kapa'a Water Quality: Rainfall Event Data

Sample Date	Time	Station	TSS (mg/l)	Turbidity (NTU)	TN (µg/l)	TP (µg/l)	Comment
11/26/01	10:28	1	26.7	49	---	---	Trigger ISCO at 10:28
11/26/01	12:28	1	29.7	47.7	---	---	
11/26/01	14:28	1	41.7	55.2	---	---	
11/26/01	16:28	1	35.5	46.5	---	---	
11/26/01	18:28	1	30	36.2	---	---	
11/26/01	20:28	1	44	56.3	---	---	
11/26/01	22:28	1	670	1090	---	---	
11/27/01	0:28	1	2700	5350	---	---	
11/27/01	2:28	1	2070	4880	---	---	
11/27/01	4:20	4	22980	33300	4980	19100	stream @ 10ft^/sec
11/27/01	4:28	1	1080	2440	---	---	
11/27/01	4:40	4a	1630	3220	1730	2200	48" culvert Flow est. 2.2 ft^3/sec
11/27/01	5:00	3	103	118	2270	607	48" culvert Flow est. 2.2 ft^3/sec
11/27/01	5:30	2	93	132	2490	630	
11/27/01	5:45	1	2870	5740	2640	3470	Flow est 1.5 ft/sec ~6" above normal
11/27/01	6:28	1	452	897	---	---	
11/27/01	8:28	1	191	404	---	---	
11/27/01	14:14	1	566	923	1820	940	flow much reduced
11/27/01	14:50	4	229	432	---	299	Flow only ~ 3gal/sec
11/27/01	15:00	3	7.8	7.26	4160	222	48" culvert flow est ~0.25ft^3/sec
12/12/01	22:30	1	15	39.2	3470	161	Grab, started isco at 2-hr interval
12/13/01	7:30	4	219	158	2870	350	no flow @ site3
12/13/01	8:45	1	46.7	75.8	3390	275	No flow visible
01/28/02	17:30	1	26.3	39.4	1130	180	No visible flow
01/28/02	17:45	2	127	364	3430	640	flow 5 gpm
01/29/02	2:15	6	1780	262	711	5050	4'culvert 6"deep at 3'/s = 2cfs
01/29/02	2:20	6a	918	10700	660	1950	Street runoff sample ~0.1 cfs
01/29/02	2:30	4	554	17500	1680	9900	No flow est
01/29/02	2:45	5	396	10400	518	2520	Sample at inlet to pond - no overflow
01/29/02	2:55	3	106	230	1330	480	Grab, apx 4 cfs
01/29/02	3:05	2	112	140	4170	430	Still raining, but less volume
01/29/02	3:20	1	169	307	1230	750	At road - on swamp side
01/29/02	9:20	7	754	10800	2390	1450	100m from top of quary -flow =4.5 cfs
01/29/02	9:30	6	27	415	1740	1180	right tunnel
01/29/02	9:30	6	79.3	197	1840	1150	left tunnel - fwy drain
01/29/02	10:00	5	556	102	6860	850	pond inlet, not runoff
01/29/02	10:20	3	1170	33.6	1670	290	4' culvert @8'/s 22" wide=2.3cfs
01/29/02	10:50	1	880	870	2650	1750	

Table 4.2. (continued)

03/30/02	7:55	3a	44	50.7	18200	258	Grab sample
03/30/02	0:01	3b	74200	124000	51500	30300	Level triggered
05/05/02	13:00	4	2850	4540	1623	3900	1 gps right pipe (fwy)
05/05/02	13:00	4	7380	10400	778	3280	1 cfs
05/05/02	13:30	2	534	478	2120	1180	Surface clogged with plants, no flow
05/05/02	13:45	1	30	36.7	1050	280	Clear
05/06/02	0:01	3	34950	45300	5310	870	
05/06/02	4:45	1	12.7	22.2	1310	190	Clear
05/06/02	13:45	1	36	60.3	3280	320	Clear
05/06/02	19:45	1	245	471	1450	980	Some color
05/06/02	20:00	3	11200	22150	5250	320	
05/06/02	20:00	4	13300	17500	923	680	
05/06/02	22:45	1	700	756	1550	1920	Red
05/07/02	0:01	4	8200	9180	1430	1900	flow est = 0.5cfs, grey sed. in sample
05/07/02	0:01	5	2210	121	5020	3290	Much sediment, est triggered at 04:15
05/07/02	7:00	5	847	237	14800	870	Reservoir finally overflowed
05/07/02	7:20	4	171	283	3460	2210	0.5 cfs
05/07/02	8:00	3	92.7	168	1210	620	Lots of bubbles at site, flow ~0.5 cfs
05/07/02	8:45	1	380	894	1790	980	Evidence of road overflow during night
05/08/02	6:15	1	347	683	2120	830	no flow, still brown

The results of Kapa'a Stream heavy metals analyses by Hawaii DOH and others are summarized below in Table 4.3 (These data are from Table 4.5 in Oceanit 2002).

Table 4.3. Dissolved Metals from Kapa`a Stream Samples

	Mo	Be	As	Ba	Cd	Sb	Cu	Cr	Mn	Fe	Pb	Hg	Mg	Ni	Se	Ag	Zn
Site 1 (*1)							<.20			350			56000				<20
Site 1 (*2)							<20			90			425000				<20
Site 1 (*4)			<5	134	<1		<5	<5			<1			13		<1	<10
Site 1	<5	<1	<2	74.6	<.2	<2	<50	<2	<5		<5	<.5		<5	<5		
Site 2	<5	<1	<2	75.5	<.2	<2	<50	<2	107		<5	<.5		<5	<5		
Site 2a – weep	<5	<1	2.48	196.	<.2	<2	<50	<2	2970		<5	<.5		10.4	5.55		
Site 3	<5	<1	<2	30.3	<.2	<2	<50	<2	<5		<5	<.5		<5	<5		
Site 3	<5	<1	<2	31.1	<.2	<2	<50	<2	480		<5	<.5		7.64	<5		
Site 3	<5	<1	<2	32.1	<.2	<2	<50	<2	300		<5	<.5		<5	<5		
Site 4 (*3)				191	<1		<13	<5			<1			6		1	30
Site 4 (*4)			<5	35	<1		<5	<5			<1			6		<1	<10
Site 4	5.39	<1	<2	<10	<.2	<2	<50	7.90	<5		<5	<.5		<5	<5		
Site 4	5.31	<1	<2	<10	<.2	<2	<50	na	<5		<5	<.5		<5	<5		
Site 4	<5	<1	<2	<10	<.2	<2	<50	<2	<5		<5	<.5		<5	<5		
Site 4	5.31	<1	<2	18.3	<.2	<2	<50	<2	<5		<5	<.5		<5	<5		
Site 5	<5	<1	<2	<10	<.2	<2	<50	<2	13		<5	<.5		<5	<5		
Standard, Acute	na	3000	360	ns	2	na	13	16	ns	ns	65	2.4	ns	470	20	3.2	120
Standard, Chronic	na		190	ns	0.25	na	9	11	ns	ns	2.5	0.55	ns	52	5	1.9	120

Standards are criteria for fresh waters with 100 mg/l total hardness as $CaCO_3$

*1: 8-12-92 "Sta 4" Kapa'a Landfill Leachate Inorganic Analyses

*2: 8-25-93 "Sta 4" EPA mthd 600

*3: 5-22-95 Oceanit, 1995

*4: 4-17-95 Oceanit, 1995

Balance of data analyzed by State DOH laboratory on samples collected 5-7-02 using EPA method 200.8 or 200.9

Initial State DOH Screening by Mass Spectrophotometer did not indicate the presence of high levels of the following elements:

-Be B Na Mg Al Si P S Cl K Ca Sc Ti V Cr Fe Co Zr Te I Cs La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu Hf Ta W Re Os Ir Pt Au Bi Th U

Chapter 5
Existing Conditions

5.1 Calculation Methods

The principal objective of calculation methods in this analysis of existing conditions is to relate stream flows and pollutant concentrations to individual contributions from identified sources of baseflow volumes, storm runoff, and pollutant loadings. Sources in each sub-basin are identified as land use categories, e.g., forest/brush, landfill, industrial, etc. These methods are a series of mass balance calculations described in mathematical detail in Appendix A, diagrammed in Figures 5-1 and 5-2, and summarized as follows.

Dry Weather Baseflows

Dry weather seasonal baseflows are determined from a flow recession model developed for the adjacent Kawa Stream watershed (DOH 2005). In this model, baseflow is a direct function of accessible soil/ground water storage. Soil water volume increases with infiltration of precipitation and is depleted by discharge to baseflow, evapotranspiration, and percolation to deep groundwater. Infiltration and evapotranspiration are both curtailed by impervious surfaces. Infiltration is further reduced by the fraction of impervious surface that is connected directly to a storm sewer collection system. Thus the primary properties that determine baseflow volume contributions from each source are the source area, impervious fraction, and connected fraction of the impervious area. Also part of the calculation is geography as precipitation (thus infiltration) varies with location in the watershed in accord with PRISM seasonal rainfall distributions.

Characteristic soil water concentrations of TSS, TN, and TP are estimated for each land use category, based first on reported groundwater concentration data and then adjusted to reflect observed dry weather Kapa'a Stream concentrations. Baseflow pollutant load contributions from each source are then the products of the categorical soil water concentrations and the baseflow volume contribution from the source. Sub-basin baseflow volume and pollutant load contributions are the sum of individual contributions from each land use category source in the sub-basin.

Wet Weather Storm Flows

Runoff volumes for individual storm events are determined from the well established SCS runoff formulation (USDA 1986) where the hydrologic effects of land use, cover, imperviousness, and soil properties are conjoined in a single curve number (CN) value for each individual source. Rainfall distributions among source locations for individual storm events are considered to be proportional, on average, to PRISM seasonal rainfall distributions.

Characteristic storm runoff concentrations of TSS, TN, and TP are estimated for each land use category, based first on reported stormwater runoff data and then adjusted to reflect observed Kapa’a watershed runoff concentrations. Storm flow pollutant load contributions from each source are then the products of the categorical runoff concentrations and the storm runoff volume contribution from the source. Sub-basin runoff volume and pollutant load contributions are the sum of individual contributions from each land use category source in the sub-basin.

Sediment Retention Facilities

In several of the sub-basin areas, storm event runoff volumes are intercepted by a sediment retention pond. Each of these ponds is characterized by an average initial water volume and pollutant concentration and a maximum volume retention capacity. For small storms with sub-basin runoff volumes less than the available pond retention capacity, the entire runoff volume during the event is retained (this retained runoff volume declines by evaporation and exfiltration between events to the initial pond volume and pollutant concentrations decay to their initial levels). For larger storms, the net sub-basin runoff volume discharged to Kapa’a Stream is reduced by the retention capacity of the pond. Pollutant concentrations in the runoff discharged are reduced by dilution with the lower pollutant concentrations in the initial retention pond volume.

Streamflows and Water Quality

Streamflows in and pollutant loadings to each stream segment are the sum of inflows from its tributary sub-basin(s) and outflows from the immediately upstream segment. Portions of the inflowing pollutant loadings are considered to be assimilated within the segment by sedimentation and/or biological uptake. By either mechanism, assimilation is proportional to the stream segment surface area and to pollutant concentration.

Dry weather conditions are regarded as steady state. Stream segment volume outflows are equal to total inflows. Pollutant load outflows are equal to total inflowing loads less the assimilation within the segment. For a storm event, total sub-basin contributions are the sum of net runoff contributions and seasonal baseflow contributions. Streamflow is considered to increase over a “time of concentration” from baseflow to an event-maximum level that remains for the event duration and then declines back to the baseflow level. Event mean streamflows and pollutant concentrations for the event are calculated as their averages over an event period of rainfall duration plus the estimated “time of concentration.”

These calculation procedures for (a) baseflow and (b) storm events are diagrammed in Figures 5-1(a) and 5-1(b).

Figure 5.1(a). Kapa'a baseflow calculation schematic

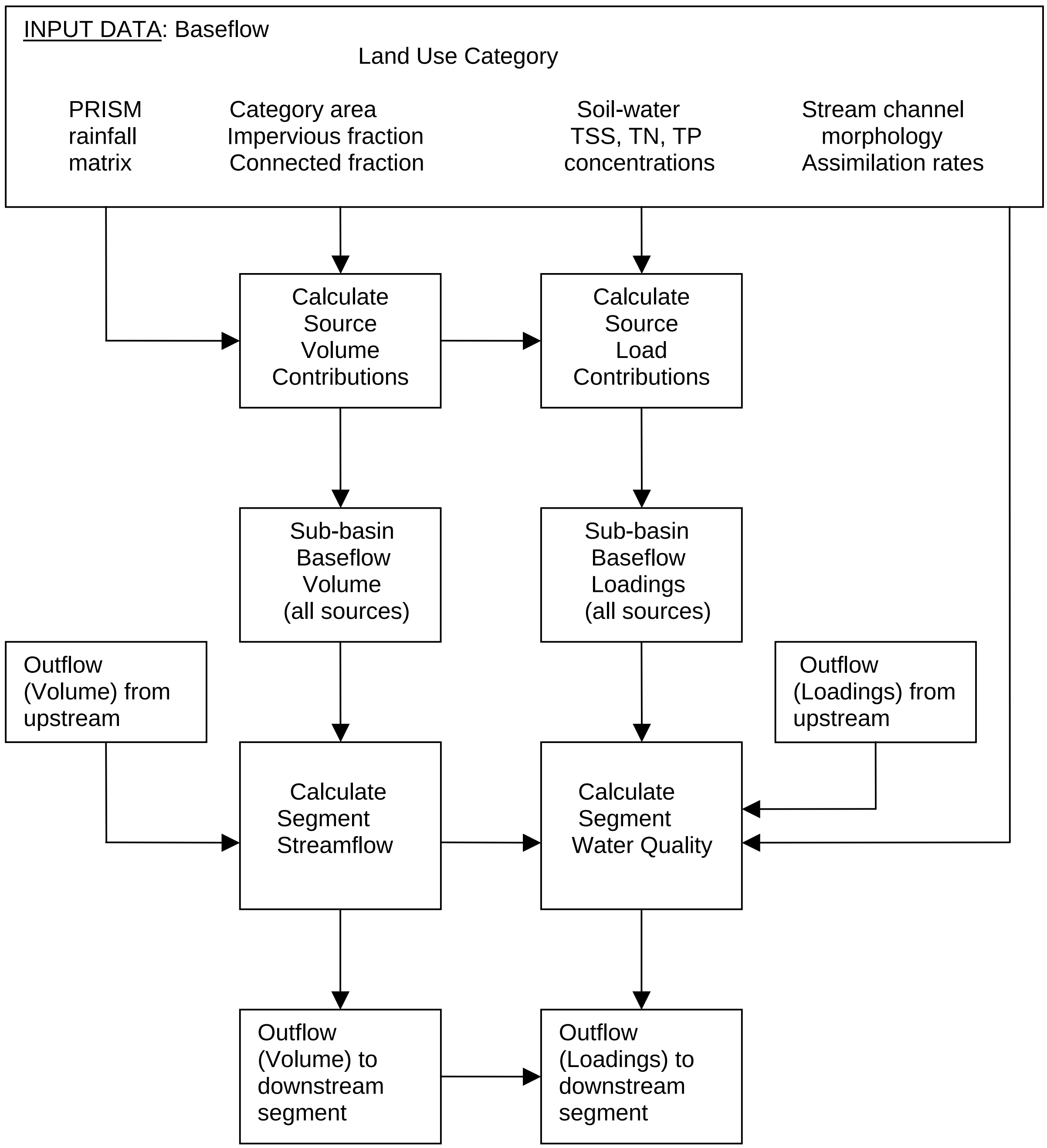
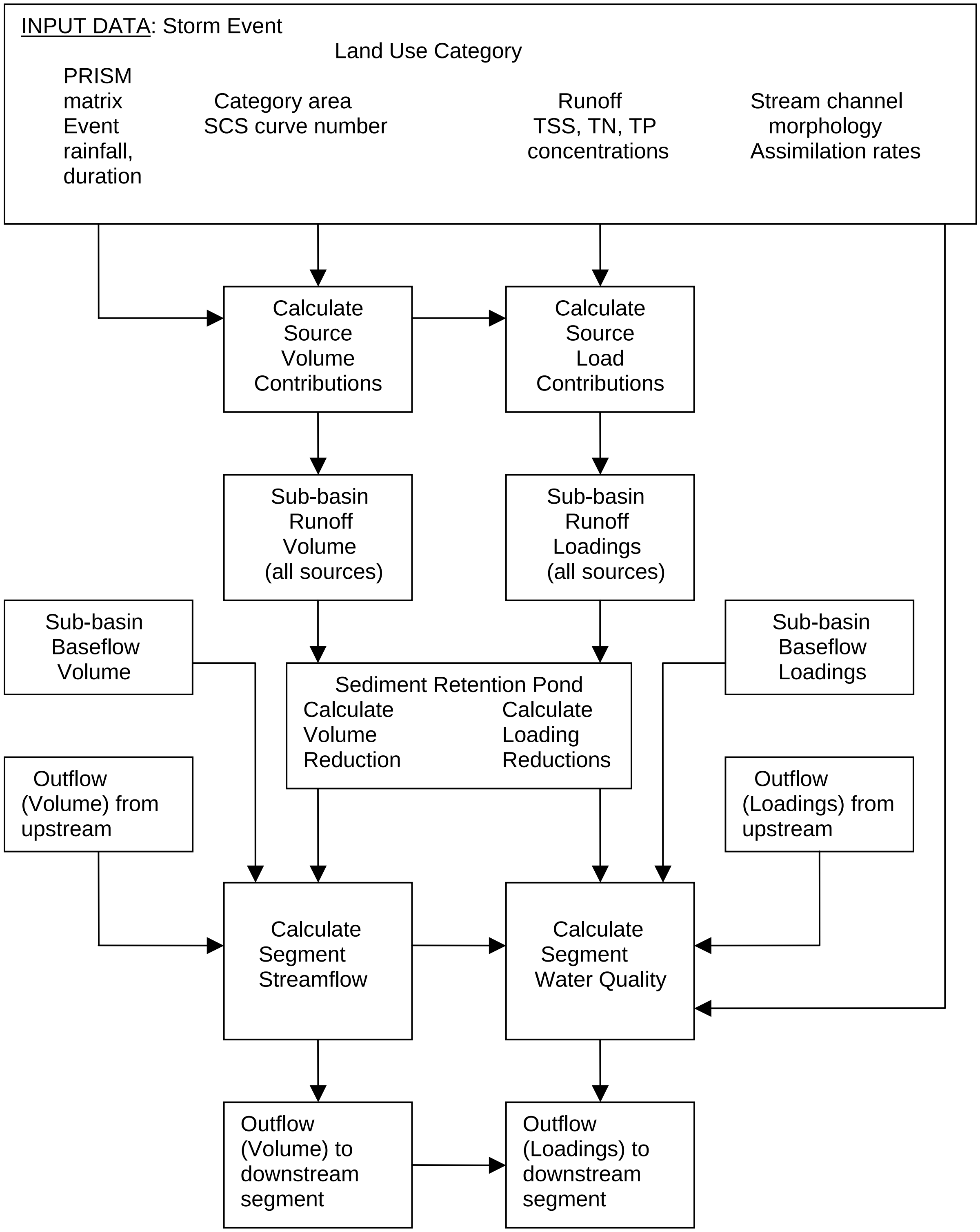


Figure 5.1(b.) Kapa'a storm event calculation schematic



5.2 Hydrologic Properties

Baseflow, storm runoff, and resulting streamflow characteristics of the Kapa'a watershed are determined by expressions described in Appendix A and hydrologic properties that are in turn determined by topography, soils, land use, land cover, human activity, and climate in the individual sub-basins of the watershed. The important properties for the existing Kapa'a watershed conditions are summarized in Table 5.1.

Table 5.1. Hydrologic Properties: Kapa'a Stream Watershed.

Sub-basin	Land Cover	Area (acres)	Impervious fraction	Impervious fraction (connected to drainage system)	SCS* CN*	Seasonal Rainfall Dry (mm)	Seasonal Rainfall Wet (mm)
A	Forest/brush	90.8	0	0	55	604	1084
A	Highway	5.2	0.57	0.5	89	604	1084
B	Forest/brush	31	0	0	56	590	1115
B	Quarry	185	0.1	0	85	570	1075
B	Roads	2	0.4	0.5	89	555	1068
C	Forest/brush	13	0	0	56	555	1068
C	Highway	4	0.57	0.5	89	555	1068
D	Eroded	27.6	0	0	86	555	1068
D	Highway	1.4	0.57	0.5	89	555	1068
E	Forest/brush	15	0	0	58	520	1050
E	Industrial	1.4	0.8	0	88	526	1019
E	Roads	3.6	0.75	0.5	89	529	1053
E	Highway	4	0.57	0.5	89	519	1053
F	Forest/brush	40	0	0	56	556	1059
F	Landfill	55.3	0	0	86	526	1030
F	Roads	2.7	0.67	0.5	85	526	1030
G	Forest/brush	28.3	0	0	78	509	1034
G	Industrial	28.6	0.8	0	88	504	994
G	Highway	3.1	0.57	0.5	89	504	994
H	Forest/brush	93	0	0	56	548	1054
H	Landfill	30.9	0	0	86	527	1018
H	Roads	2.1	0.67	0.5	85	527	1018
I	Landfill	5.6	0	0	86	504	994
I	Roads	2.4	0.75	0.5	89	504	994
J	Forest/brush	25.9	0	0	56	490	975
J	Landfill	28	0	0	86	500	945
J	Highway	5.1	0.57	0.5	89	500	980
K	Landfill	27	0	0	86	489	945
K	Roads	1	0.67	0.5	89	489	945
L	Landfill	34.2	0	0	86	513	963
L	Industrial	24	0.8	0	88	513	963
L	Roads	3.8	0.4	0.5	85	513	963
	Total:	825					

*SCS CN = Soil Conservation Service Curve Number (U.S. Department of Agriculture)

5.3 Pollutant Source Concentrations

Pollutant concentrations that are associated in this analysis with land use/land cover sources are presented in Table 5.2. Baseflow concentrations were initially developed from reported mean USGS NAWQA groundwater concentrations (Hunt 2004) and then adjusted according to 2001-2002 baseline Kapa'a Stream water quality data and stream assimilation rates assumed in this analysis. Storm runoff concentrations were initially developed from event mean concentration (EMC) data reported by EPA's National Urban Runoff Program (EPA 1983, Pitt et al 2003) and other estimates of nonpoint source pollutant loading rates (Shannon and Brezonik 1972, Uttermark et al 1974). These initial estimates were then adjusted according to the Kapa'a Stream water quality data and the calibrated stream assimilation rates. Stream assimilation rates are represented as particle sedimentation velocities and their calibrated values are also included in Table 5.2.

Table 5.2. Pollutant Source Concentrations (mg/l) and Assimilation Rates

	Baseflow			Storm Runoff		
Land Use	TSS	TN	TP	TSS	TN	TP
Forest/brush	50	1	0.4	200	1.5	1
Eroded	50	2	0.4	9,500	2	4
Landfill	150	4	1.5	3,000	4	1
Quarry	100	2	0.4	5,000	2	1
Industrial	150	2	0.4	400	2.5	0.5
Roads	150	2	0.4	500	1.5	1
Highway	50	1	0.4	100	1	1

	TSS	TN	TP
sediment velocity (ft/sec)	0.0005	0.00004	0.0001

5.4 Sediment Retention Ponds

In three of the sub-basins (B, H, L), storm runoff is diverted to sediment retention ponds before discharge to Kapa'a Stream. For relatively small storm events, the runoff from these sub-basins may be completely retained without discharge. For runoff volumes greater than the available pond retention volume, the runoff is considered to mix with the existing (initial) pond volume and pollutant concentrations before discharging the difference between runoff and available retention volumes. Pre-runoff retention pond concentrations of total suspended solids, nitrogen, and phosphorus are assumed for this calculation to be 100, 1, and 0.2 mg/l, respectively. Hydraulic properties of the sediment retention ponds are listed in Table 5.4 below.

5.5 Watershed Hydraulics

Kapa'a Stream channel properties assumed for this analysis are summarized in Table 5.3.

Table 5.3. Kapa'a Stream Channel Hydraulic Properties

				Stream Channel				Flood Plain	
Segment	Description	from RM*	to RM*	Width (ft)	Depth (ft)	Manning n	Slope (ft/ft)	a(hyper) (ft)	Manning n
1	Headwaters	1.94	1.26	1	1	0.04	0.078	299	0.06
2	Upper Ameron	1.26	0.89	3	6	0.04	0.044	160	0.06
3	Lower Ameron	0.89	0.55	2	1	0.04	0.036	412	0.07
4	Middle reach	0.55	0.29	3	1	0.04	0.076	1513	0.07
5	Canal	0.23	0	5	3	0.04	0.004	12000	0.07
6	Lower reach	0.29	0	2	1	0.04	0.007	12510	0.07
7	Outflow to Marsh	0							
8	Outflow to Marsh	0							

*RM = River Mile (miles from stream mouth)

Storm runoff from some sub-basin areas is intercepted by drainage collection systems and transmitted to the head of a stream segment as a point discharge. The runoff from other sub-basins is dispersed along the length of the stream segment as a nonpoint source. Sub-basin contributions to baseflow in all stream segments are considered in this analysis as groundwater and other dispersed source inflows. The distribution and form of sub-basin contributions of flow and pollutant loads to individual stream segments is displayed in Table 5.4.and Figure 5-2. The distribution of baseflow contributions among individual stream segments assumed in this table is likely not precisely correct. However, the end results of baseflow and water quality in the lower portion of Kapa'a Stream are relatively insensitive to the distribution of their upstream contributions.

Table 5.4. Pollutant Source Discharge Locations

	Discharge Locations			Sediment Ponds		
Sub-basin	Point Source to Seg.	NonPoint Source to Seg.	Baseflow to Seg.	Area (ac.)	Depth-full (ft)	Depth-pre-storm (ft)
A		1	1			
B	2		2	8.03	20	10
C		2	2			
D	3		3			
E		3	3			
F	4		3			
G		4	4			
H	6		4	0.46	6	3
I	6		5			
J		6	6			
K		5	5			
L	8		8	0.23	6	3

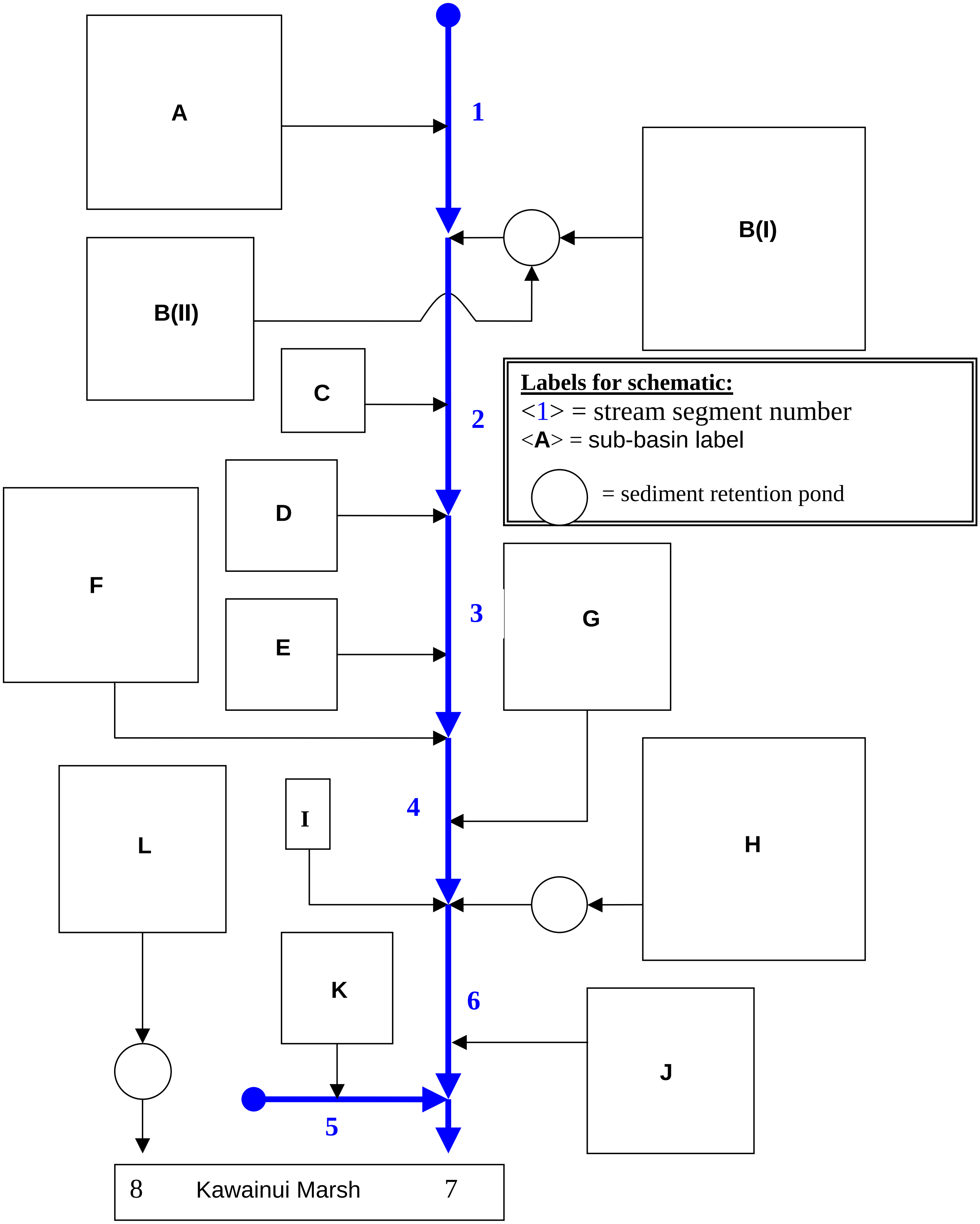


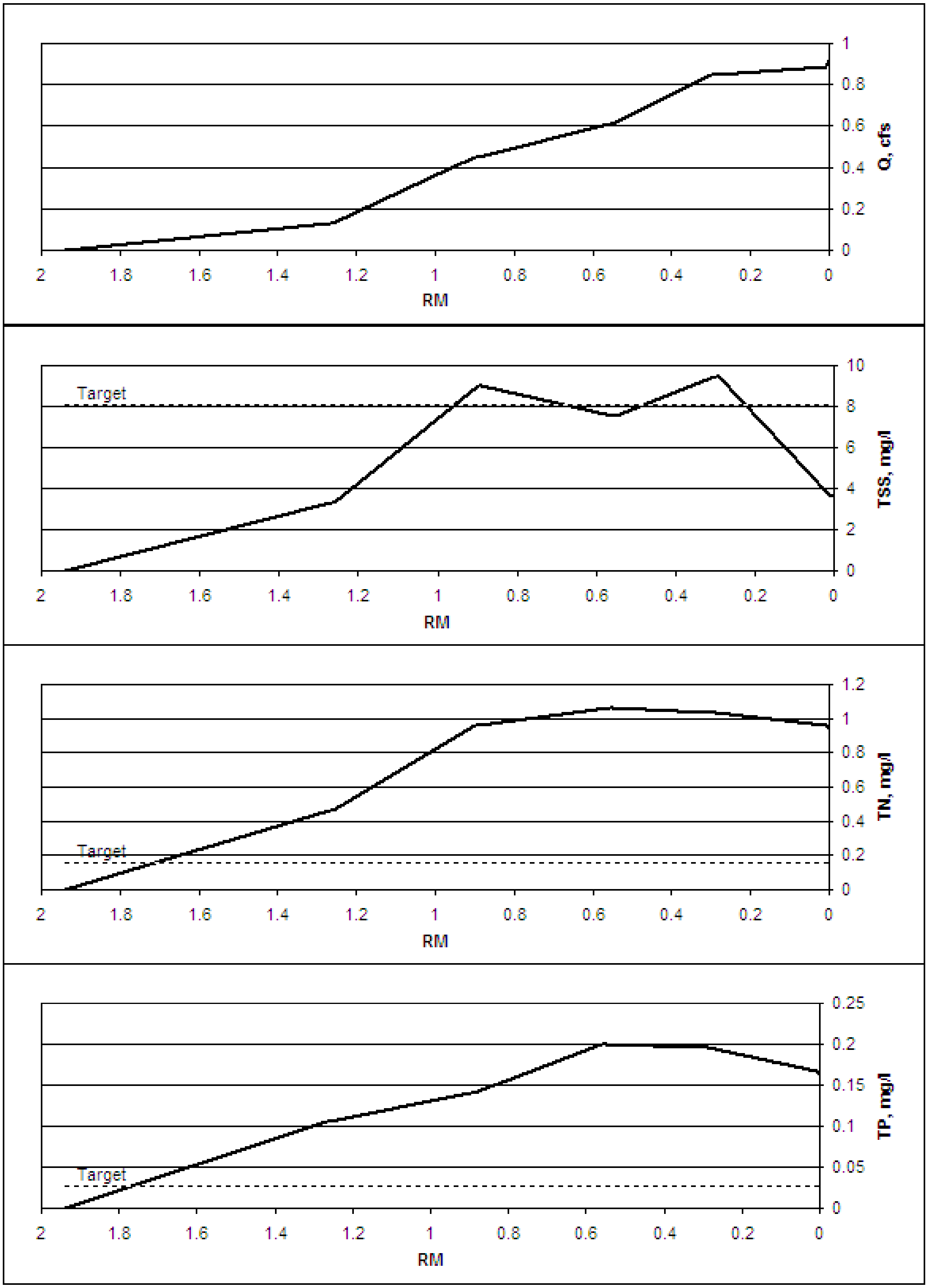
Figure 5-2. Kapa'a storm runoff flow schematic

5.6 Existing Dry Season Conditions

Dry Season Baseflow. The highest CN-value for the land use categories in the Kapa'a watershed is 89 (highway). This value translates into a minimum rainfall of 0.25-inch before runoff will occur. During an average 86% of the dry season days, rainfall at the Pali Golf Course weather station will be less than this minimum rainfall amount and baseflow conditions should prevail. Calculated baseflow and pollutant load contributions for this 86% time period are summarized in Table 5.5. Calculated base streamflow and water quality along the length of Kapa'a Stream are displayed in Figure 5-3.

Table 5.5. Existing Dry Season Baseflow and Pollutant Load Contributions

Dry Weather Season Sub-basin	Land Use	Baseflow Flow (cfs)	TSS (kgd)	TN (kgd)	TP (kgd)
A	Forest/brush	0.12	15	0.29	0.12
A	Highway	0.01	1	0.02	0.01
B	Forest/brush	0.04	5	0.10	0.04
B	Quarry	0.26	63	1.26	0.25
B	Roads	0.00	1	0.01	0.00
C	Forest/brush	0.01	2	0.04	0.01
C	Highway	0.01	1	0.01	0.01
D	Eroded	0.03	4	0.15	0.03
D	Highway	0.00	0	0.01	0.00
E	Forest/brush	0.01	2	0.04	0.01
E	Industrial	0.00	1	0.02	0.00
E	Roads	0.01	2	0.03	0.01
E	Highway	0.01	1	0.01	0.01
F	Forest/brush	0.04	5	0.11	0.04
F	Landfill	0.05	19	0.51	0.19
F	Roads	0.00	1	0.02	0.00
G	Forest/brush	0.03	3	0.06	0.03
G	Industrial	0.07	26	0.35	0.07
G	Highway	0.00	0	0.01	0.00
H	Forest/brush	0.10	12	0.24	0.10
H	Landfill	0.03	11	0.28	0.11
H	Roads	0.00	1	0.01	0.00
I	Landfill	0.00	2	0.04	0.02
I	Roads	0.00	1	0.02	0.00
J	Forest/brush	0.02	2	0.05	0.02
J	Landfill	0.02	7	0.19	0.07
J	Highway	0.01	1	0.02	0.01
K	Landfill	0.02	6	0.17	0.06
K	Roads	0.00	0	0.01	0.00
L	Landfill	0.03	10	0.25	0.10
L	Industrial	0.06	22	0.29	0.06
L	Roads	0.00	2	0.02	0.00
	Totals:	1.00	229	4.64	1.38



RM = River Miles (miles from stream mouth)

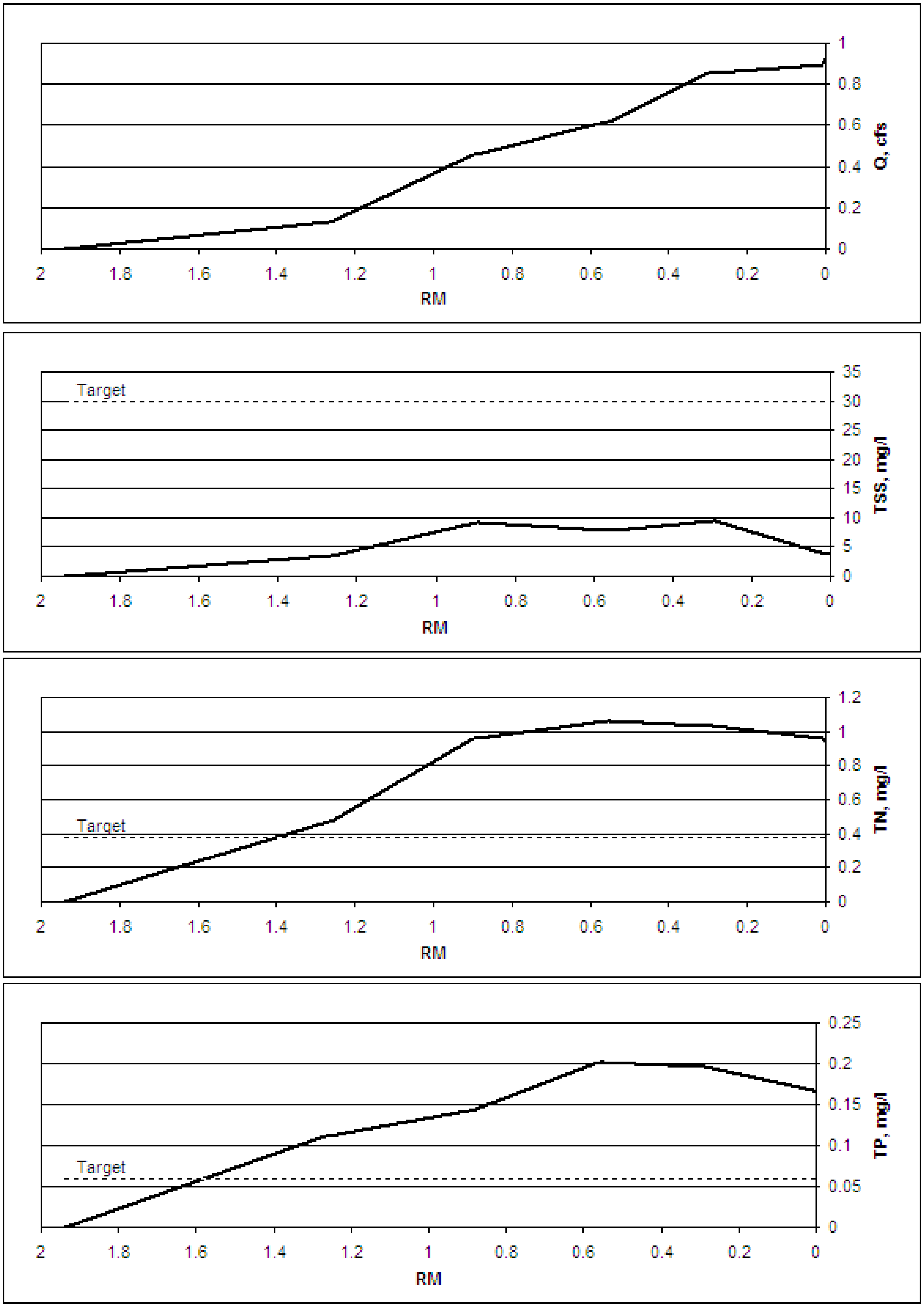
Figure 5-3. Calculated dry season baseflow and water quality.

Dry Season 10% Rainfall Event. Rainfall at Pali Golf Course is equal to or greater than 0.35-inch during an average 10% of the dry season days. Calculated runoff and pollutant load contributions for this 0.35-inch rainfall event are summarized in Table 5.6. In this table, the columns Rnet, SSnet, Nnet, and Pnet account for the effects of existing sediment retention ponds. Calculations of streamflow and water quality for this 10% rainfall event are displayed in Figure 5-4.

Table 5.6. Existing Dry Season 10% Event Runoff and Pollutant Load Contributions

Dry Weather Season		10% Storm Event		P =	0.35	inch			
Sub-basin	Land Use	Runoff	Rnet*	TSS	Ssnet*	TN	Nnet*	TP	Pnet*
		(mcf)	(mcf)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
A	Forest/brush	0	0	0.00	0.00	0.00	0.00	0.00	0.00
A	Highway	5.8E-05	5.8E-05	0.16	0.16	0.00	0.00	0.00	0.00
B	Forest/brush	0	0	0.00	0.00	0.00	0.00	0.00	0.00
B	Quarry	0	0	0.00	0.00	0.00	0.00	0.00	0.00
B	Roads	8.2E-06	8.2E-06	0.12	0.00	0.00	0.00	0.00	0.00
C	Forest/brush	0	0	0.00	0.00	0.00	0.00	0.00	0.00
C	Highway	1.6E-05	1.6E-05	0.05	0.05	0.00	0.00	0.00	0.00
D	Eroded	0	0	0.00	0.00	0.00	0.00	0.00	0.00
D	Highway	5.8E-06	5.8E-06	0.02	0.02	0.00	0.00	0.00	0.00
E	Forest/brush	0	0	0.00	0.00	0.00	0.00	0.00	0.00
E	Industrial	0	0	0.00	0.00	0.00	0.00	0.00	0.00
E	Roads	6.3E-06	6.3E-06	0.09	0.09	0.00	0.00	0.00	0.00
E	Highway	4.4E-06	4.4E-06	0.01	0.01	0.00	0.00	0.00	0.00
F	Forest/brush	0	0	0.00	0.00	0.00	0.00	0.00	0.00
F	Landfill	0	0	0.00	0.00	0.00	0.00	0.00	0.00
F	Roads	0	0	0.00	0.00	0.00	0.00	0.00	0.00
G	Forest/brush	0	0	0.00	0.00	0.00	0.00	0.00	0.00
G	Industrial	0	0	0.00	0.00	0.00	0.00	0.00	0.00
G	Highway	1.3E-06	1.3E-06	0.00	0.00	0.00	0.00	0.00	0.00
H	Forest/brush	0	0	0.00	0.00	0.00	0.00	0.00	0.00
H	Landfill	0	0	0.00	0.00	0.00	0.00	0.00	0.00
H	Roads	0	0	0.00	0.00	0.00	0.00	0.00	0.00
I	Landfill	0	0	0.00	0.00	0.00	0.00	0.00	0.00
I	Roads	9.8E-07	9.8E-07	0.01	0.01	0.00	0.00	0.00	0.00
J	Forest/brush	0	0	0.00	0.00	0.00	0.00	0.00	0.00
J	Landfill	0	0	0.00	0.00	0.00	0.00	0.00	0.00
J	Highway	1.4E-06	1.4E-06	0.00	0.00	0.00	0.00	0.00	0.00
K	Landfill	0	0	0.00	0.00	0.00	0.00	0.00	0.00
L	Landfill	0	0	0.00	0.00	0.00	0.00	0.00	0.00
L	Industrial	0	0	0.00	0.00	0.00	0.00	0.00	0.00
L	Roads	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	Totals:	0.0001	9.5E-05	0.47	0.35	0.00	0.00	0.00	0.00

*Net pollutant load contributions after accounting for effects of existing sediment retention ponds



RM = River Miles (miles from stream mouth)

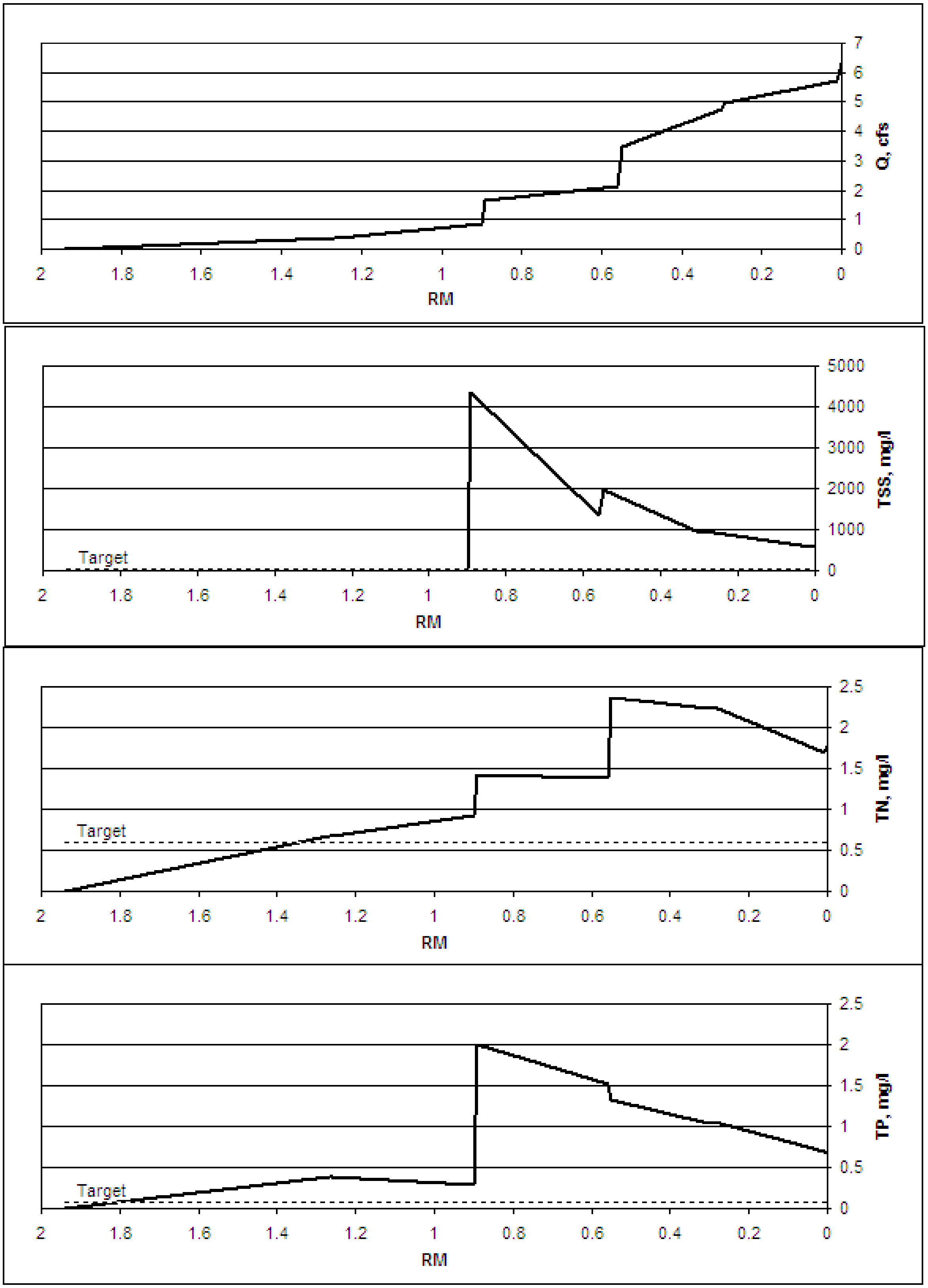
Figure 5-4. Calculated dry season 10% event streamflow and water quality.

Dry Season 2% Rainfall Event. Rainfall at Pali Golf Course is equal to or greater than 1.27-inch during an average 2% of the dry season days. Calculated runoff and pollutant load contributions for this 1.27-inch rainfall event are summarized in Table 5.7. In this table, the columns Rnet, SSnet, Nnet, and Pnet account for the effects of existing sediment retention ponds. Calculations of streamflow and water quality for this 2% rainfall event are displayed in Figure 5-5.

Table 5.7. Existing Dry Season 2% Event Runoff and Pollutant Load Contributions

Dry Weather Season		2% Storm Event		P =	1.27	inch			
Sub-basin	Land Use	Runoff	Rnet*	TSS	Ssnet*	TN	Nnet*	TP	Pnet*
		(mcf)	(mcf)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
A	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
A	Highway	0.01	0.01	20	20	0.20	0.20	0.20	0.20
B	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
B	Quarry	0.14	0.00	19,368	0	7.75	0.00	3.87	0.00
B	Roads	0.00	0.00	32	0	0.09	0.00	0.13	0.00
C	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
C	Highway	0.00	0.00	13	13	0.13	0.13	0.13	0.13
D	Eroded	0.02	0.02	5,803	5,803	1.22	1.22	2.44	2.44
D	Highway	0.00	0.00	4	4	0.04	0.04	0.04	0.04
E	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
E	Industrial	0.00	0.00	14	14	0.09	0.09	0.02	0.02
E	Roads	0.00	0.00	51	51	0.15	0.15	0.20	0.20
E	Highway	0.00	0.00	11	11	0.11	0.11	0.11	0.11
F	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
F	Landfill	0.04	0.04	3,207	3,207	4.28	4.28	1.07	1.07
F	Roads	0.00	0.00	23	23	0.07	0.07	0.09	0.09
G	Forest/brush	0.00	0.00	27	27	0.20	0.20	0.13	0.13
G	Industrial	0.02	0.02	258	258	1.61	1.61	0.32	0.32
G	Highway	0.00	0.00	8	8	0.08	0.08	0.08	0.08
H	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
H	Landfill	0.02	0.00	1,801	0	2.40	0.00	0.60	0.00
H	Roads	0.00	0.00	18	0	0.05	0.00	0.07	0.00
I	Landfill	0.00	0.00	291	291	0.39	0.39	0.10	0.10
I	Roads	0.00	0.00	31	31	0.09	0.09	0.12	0.12
J	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
J	Landfill	0.02	0.02	1,423	1,423	1.90	1.90	0.47	0.47
J	Highway	0.00	0.00	13	13	0.13	0.13	0.13	0.13
K	Landfill	0.02	0.02	1,293	1,293	1.72	1.72	0.43	0.43
L	Landfill	0.02	0.01	1,859	356	2.48	0.51	0.62	0.12
L	Industrial	0.02	0.01	225	43	1.41	0.29	0.28	0.06
L	Roads	0.00	0.00	30	6	0.09	0.02	0.12	0.02
	Totals:	0.36	0.17	35,832	12,904	26.71	13.25	11.83	6.34

*Net pollutant load contributions after accounting for effects of existing sediment retention ponds



RM = River Miles (miles from stream mouth)

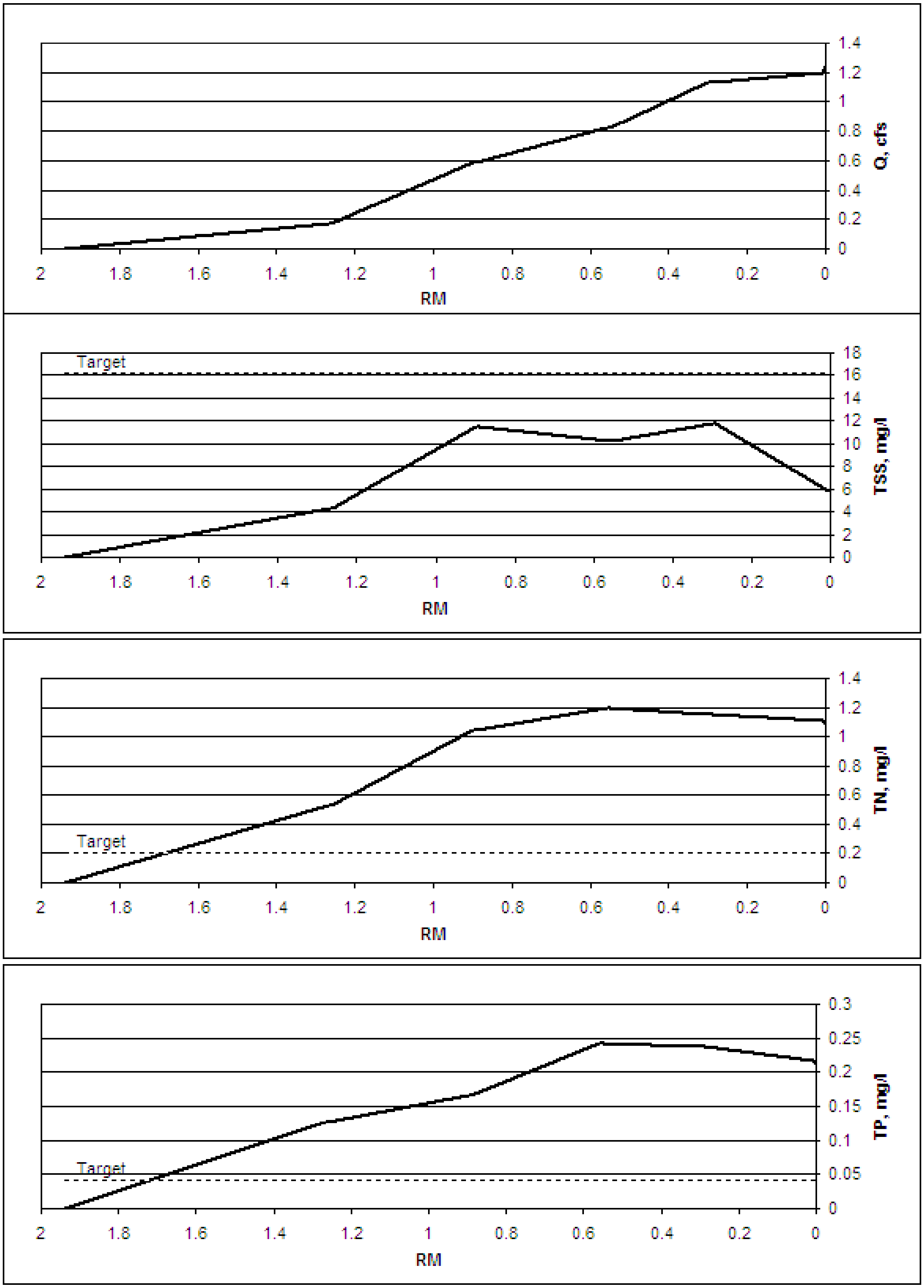
Figure 5-5. Calculated dry season 2% event streamflow and water quality.

5.7 Existing Wet Season Conditions

Wet Season Baseflow. During an average 80% of the wet season days, rainfall at the Pali Golf Course weather station will be less than the minimum 0.25-inch necessary to induce runoff. Calculations of baseflow and pollutant load contributions for this 80% time period are summarized in Table 5.8. Calculated wet seasonal baseflow and water quality along the length of Kapa’a Stream are displayed in Figure 5-6.

Table 5.8. Existing Wet Season Baseflow and Pollutant Load Contributions

Wet Weather Season Sub-basin	Land Use	Baseflow Flow (cfs)	TSS (kgd)	TN (kgd)	TP (kgd)
A	Forest/brush	0.16	19	0.39	0.15
A	Highway	0.01	1	0.02	0.01
B	Forest/brush	0.06	7	0.14	0.05
B	Quarry	0.34	83	1.65	0.33
B	Roads	0.00	1	0.02	0.00
C	Forest/brush	0.02	3	0.05	0.02
C	Highway	0.01	1	0.02	0.01
D	Eroded	0.04	5	0.21	0.04
D	Highway	0.00	0	0.01	0.00
E	Forest/brush	0.02	3	0.05	0.02
E	Industrial	0.00	2	0.02	0.00
E	Roads	0.01	2	0.03	0.01
E	Highway	0.01	1	0.02	0.01
F	Forest/brush	0.06	8	0.15	0.06
F	Landfill	0.08	28	0.75	0.28
F	Roads	0.00	2	0.02	0.00
G	Forest/brush	0.04	5	0.09	0.04
G	Industrial	0.08	30	0.40	0.08
G	Highway	0.00	1	0.01	0.00
H	Forest/brush	0.14	17	0.35	0.14
H	Landfill	0.04	15	0.41	0.15
H	Roads	0.00	1	0.02	0.00
I	Landfill	0.01	3	0.07	0.03
I	Roads	0.00	1	0.02	0.00
J	Forest/brush	0.03	4	0.07	0.03
J	Landfill	0.03	11	0.29	0.11
J	Highway	0.01	1	0.02	0.01
K	Landfill	0.03	10	0.28	0.10
L	Landfill	0.04	14	0.39	0.14
L	Industrial	0.07	25	0.33	0.07
L	Roads	0.01	2	0.03	0.01
	Totals:	1.35	305	6.32	1.92



RM = River Miles (miles from stream mouth)

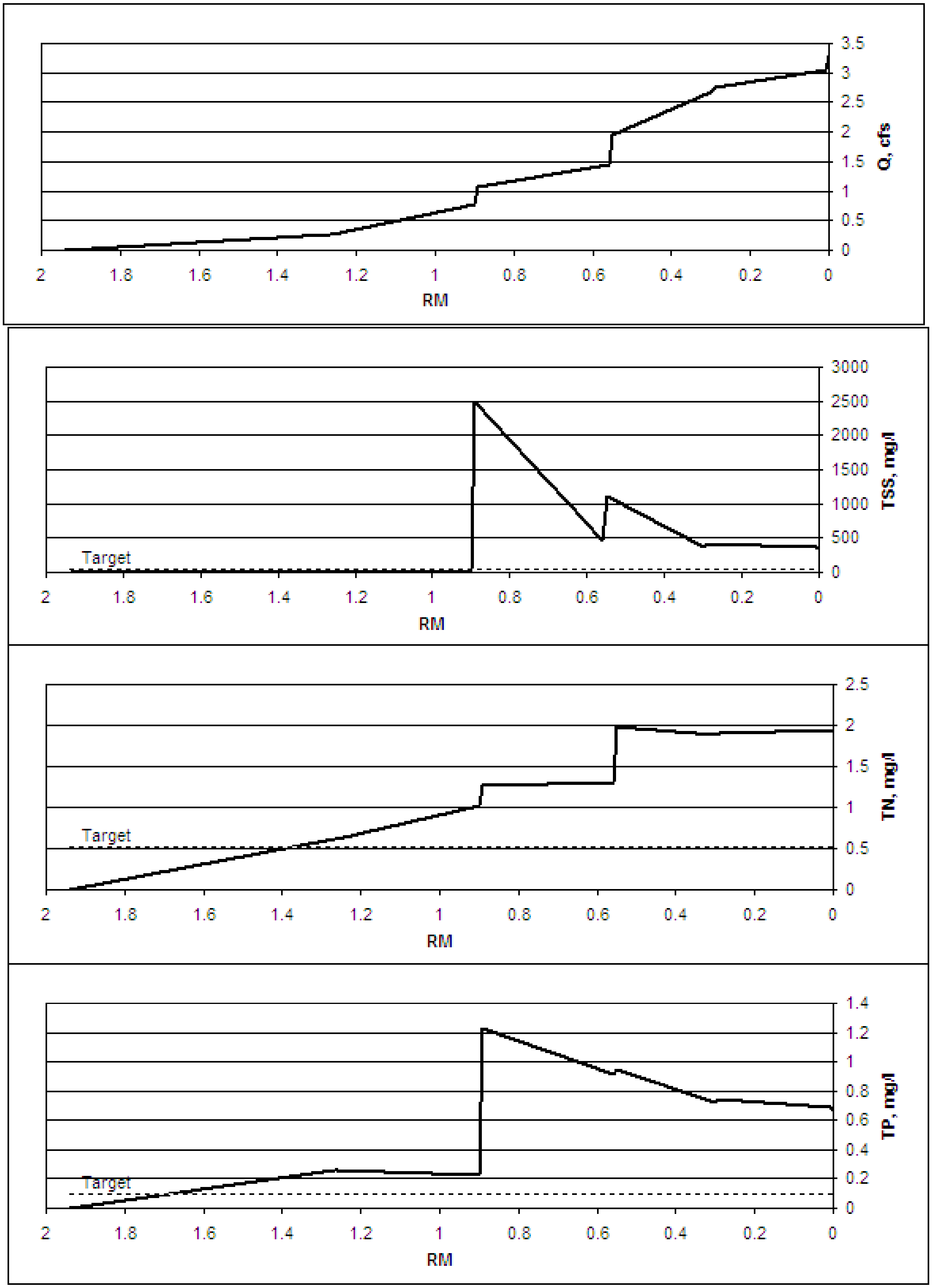
Figure 5-6. Calculated wet season baseflow and water quality.

Wet Season 10% Rainfall Event. Rainfall at Pali Golf Course is equal to or greater than 0.70-inch during an average 10% of the wet season days. Calculated runoff and pollutant load contributions for this 0.70-inch rainfall event are summarized in Table 5.9. In this table, the columns Rnet, SSnet, Nnet, and Pnet account for the effects of existing sediment retention ponds. Calculations of streamflow and water quality for this 10% rainfall event are displayed in Figure 5-7.

Table 5.9. Existing Wet Season 10% Event Runoff and Pollutant Load Contributions

Wet Weather Season		10% Storm Event		P =	0.70	inch			
Sub-basin	Land Use	Runoff	Rne*t	TSS	Ssnet*	TN	Nnet*	TP	Pnet*
		(mcf)	(mcf)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
A	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
A	Highway	0.00	0.00	6	6	0.06	0.06	0.06	0.06
B	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
B	Quarry	0.03	0.00	4,690	0	1.88	0.00	0.94	0.00
B	Roads	0.00	0.00	11	0	0.03	0.00	0.04	0.00
C	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
C	Highway	0.00	0.00	4	4	0.04	0.04	0.04	0.04
D	Eroded	0.01	0.01	1,615	1,615	0.34	0.34	0.68	0.68
D	Highway	0.00	0.00	2	2	0.02	0.02	0.02	0.02
E	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
E	Industrial	0.00	0.00	4	4	0.03	0.03	0.01	0.01
E	Roads	0.00	0.00	19	19	0.06	0.06	0.08	0.08
E	Highway	0.00	0.00	4	4	0.04	0.04	0.04	0.04
F	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
F	Landfill	0.01	0.01	896	896	1.19	1.19	0.30	0.30
F	Roads	0.00	0.00	6	6	0.02	0.02	0.02	0.02
G	Forest/brush	0.00	0.00	1	1	0.01	0.01	0.01	0.01
G	Industrial	0.01	0.01	84	84	0.53	0.53	0.11	0.11
G	Highway	0.00	0.00	3	3	0.03	0.03	0.03	0.03
H	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
H	Landfill	0.01	0.00	479	0	0.64	0.00	0.16	0.00
H	Roads	0.00	0.00	4	0	0.01	0.00	0.02	0.00
I	Landfill	0.00	0.00	79	79	0.11	0.11	0.03	0.03
I	Roads	0.00	0.00	11	11	0.03	0.03	0.04	0.04
J	Forest/brush	0.00	0.00	0	0	0.00	0.00	0.00	0.00
J	Landfill	0.00	0.00	324	324	0.43	0.43	0.11	0.11
J	Highway	0.00	0.00	4	4	0.04	0.04	0.04	0.04
K	Landfill	0.00	0.00	312	312	0.42	0.42	0.10	0.10
L	Landfill	0.01	0.00	427	0	0.57	0.00	0.14	0.00
L	Industrial	0.01	0.00	64	0	0.40	0.00	0.08	0.00
L	Roads	0.00	0.00	6	0	0.02	0.00	0.02	0.00
	Totals:	0.10	0.04	9,060	3,379	6.95	3.41	3.13	1.73

*Net pollutant load contributions after accounting for effects of existing sediment retention ponds



RM = River Miles (miles from stream mouth)

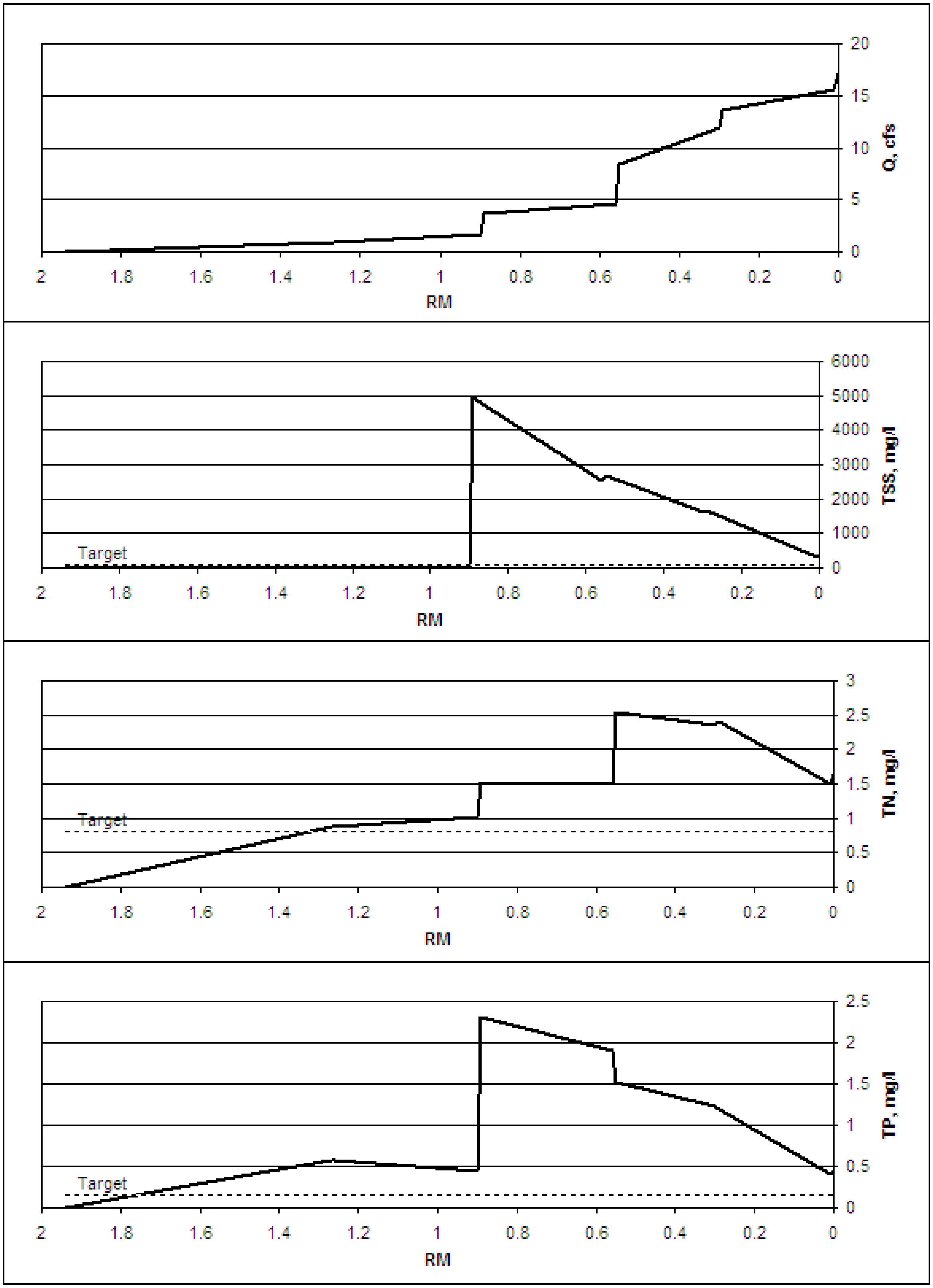
Figure 5-7. Calculated wet season 10% event streamflow and water quality.

Wet Season 2% Rainfall Event. Rainfall at Pali Golf Course is equal to or greater than 2.30-inch during an average 2% of the wet season days. Calculated runoff and pollutant load contributions for this 2.30-inch rainfall event are summarized in Table 5.10. In this table, the columns Rnet, SSnet, Nnet, and Pnet account for the effects of existing sediment retention ponds. Calculations of streamflow and water quality for this 2% rainfall event are displayed in Figure 5-8.

Table 5.10. Existing Wet Season 2% Event Runoff and Pollutant Load Contributions

Wet Weather Season		2% Storm Event		P =	2.30	inch			
Sub-basin	Land Use	Runoff	Rnet*	TSS	Ssnet*	TN	Nnet*	TP	Pnet*
		(mcf)	(mcf)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
A	Forest/brush	0.01	0.01	75	75	0.57	0.57	0.38	0.38
A	Highway	0.02	0.02	65	65	0.65	0.65	0.65	0.65
B	Forest/brush	0.01	0.00	39	0	0.29	0.00	0.19	0.00
B	Quarry	0.64	0.00	90,778	0	36.31	0.00	18.16	0.00
B	Roads	0.01	0.00	123	0	0.37	0.00	0.49	0.00
C	Forest/brush	0.00	0.00	12	12	0.09	0.09	0.06	0.06
C	Highway	0.02	0.02	49	49	0.49	0.49	0.49	0.49
D	Eroded	0.10	0.10	27,014	27,014	5.69	5.69	11.37	11.37
D	Highway	0.01	0.01	17	17	0.17	0.17	0.17	0.17
E	Forest/brush	0.00	0.00	20	20	0.15	0.15	0.10	0.10
E	Industrial	0.01	0.01	60	60	0.38	0.38	0.08	0.08
E	Roads	0.02	0.02	216	216	0.65	0.65	0.86	0.86
E	Highway	0.02	0.02	48	48	0.48	0.48	0.48	0.48
F	Forest/brush	0.01	0.01	36	36	0.27	0.27	0.18	0.18
F	Landfill	0.19	0.19	16,053	16,053	21.40	21.40	5.35	5.35
F	Roads	0.01	0.01	123	123	0.37	0.37	0.49	0.49
G	Forest/brush	0.06	0.06	325	325	2.44	2.44	1.62	1.62
G	Industrial	0.10	0.10	1,179	1,179	7.37	7.37	1.47	1.47
G	Highway	0.01	0.01	34	34	0.34	0.34	0.34	0.34
H	Forest/brush	0.01	0.01	81	29	0.61	0.22	0.41	0.15
H	Landfill	0.10	0.05	8,788	3,093	11.72	4.32	2.93	1.06
H	Roads	0.01	0.00	93	33	0.28	0.10	0.37	0.14
I	Landfill	0.02	0.02	1,527	1,527	2.04	2.04	0.51	0.51
I	Roads	0.01	0.01	132	132	0.39	0.39	0.53	0.53
J	Forest/brush	0.00	0.00	12	12	0.09	0.09	0.06	0.06
J	Landfill	0.08	0.08	6,977	6,977	9.30	9.30	2.33	2.33
J	Highway	0.02	0.02	55	55	0.55	0.55	0.55	0.55
K	Landfill	0.08	0.08	6,728	6,728	8.97	8.97	2.24	2.24
L	Landfill	0.10	0.09	8,816	6,514	11.75	8.82	2.94	2.20
L	Industrial	0.08	0.07	939	694	5.87	4.40	1.17	0.88
L	Roads	0.01	0.01	153	113	0.46	0.34	0.61	0.46
	Totals:	1.77	1.03	170,620	71,284	130.66	81.21	57.80	35.40

*Net pollutant load contributions after accounting for effects of existing sediment retention ponds



RM = River Miles (miles from stream mouth)

Figure 5-8. Calculated wet season 2% event streamflow and water quality.

5.8 Summary Observations

Baseflow volumes shown in Figures 5-3 and 5-5 were not found in the 2002 Survey. However, 2002 was preceded by four years of continuous drought – annual rainfall amounts were less than half the 30-year annual average. Baseflow levels of at least 1 cfs were observed as far upstream as stream segment 2 during a more nearly average rainfall year (DOH 2005).

Calculated baseflow contributions from individual land uses/land covers are roughly proportional to the areas of those uses/covers, with 38% of baseflow originating in the 41% of the watershed area that is forest/brush, and 25 and 16% of baseflow originating in the 22 and 22% of the area that are quarry and landfill, respectively. Baseflow nutrient contributions, however, are weighted more toward disturbed land areas. Landfill, quarry, and forest/brush areas contribute 33, 27, and 20%, respectively, of total baseflow nitrogen and 41, 18, and 27%, respectively, of total baseflow phosphorus.

For the dry season 10% rainfall event (0.35-inch), the small amounts of runoff and TSS, TN, and TP loads are entirely from highway and road areas. With increasing rainfall, the primary source of runoff and pollutant loading quickly becomes the landfill areas: first Kapa'a landfill and then, as its sediment pond capacity is exceeded, Kalaheo landfill. With rainfall of 0.70-inch (wet season 10% event), 1.27-inch (dry season 2% event), and 2.30-inch (wet season 2% event), the contributions of total runoff from the landfill areas are 43, 47, and 50%, respectively. Landfill area contributions of total suspended solids loads for these rainfall events are 48, 51, and 57%; contributions of total nitrogen loads are 63, 66, and 68%; and contributions of total phosphorus loads are 31, 35, and 39%.

Storm runoff loads of suspended solids and phosphorus loads from the eroded area of Sub-basin D are greatly in excess of the relative area proportion (3%) of this small sub-basin. For the critical 0.70, 1.27, and 2.30-inch rainfall events, Sub-basin D contributes 48, 45, and 38% of the total suspended solids load and 39, 39, and 32% of the total phosphorus load.

The runoff and pollutant load contributions calculated above are net amounts discharged, i.e., they account for the runoff capture and storage provided by the existing sediment retention pond systems. For the 4 rainfall conditions, this accounting results in the complete capture and zero discharge of runoff and pollutant loads from the Ameron Quarry area even though initial runoff volumes and pollutant loads generated within the quarry system are significant.

Chapter 6
TMDL Allocations

6.1 Conditions and Criteria

The TMDLs in this analysis were developed for the six conditions: baseflow, 10% storm event, and 2% storm event for both dry and wet weather seasons. Baseflow (non-runoff) conditions apply during an average 86% of the dry season days. Rainfall (Pali Golf Course weather station) is equal to or greater than 0.35-inch during 10% and 1.27-inch during 2% of the dry season days. Average runoff durations (rainfall duration plus time of runoff concentration) were estimated as 4 and 8 hours, respectively, for the 10% and 2% dry season rainfall events.

Baseflow conditions apply during an average 80% of the wet season days. Rainfall is equal to or greater than 0.70-inch during 10% and 2.30-inch during 2% of the dry season days. Average runoff durations were estimated as 6 and 15 hours, respectively, for the 10% and 2% wet season rainfall events.

Water quality criteria for the 10% and 2% rainfall events are the water quality standards not to be exceeded during more than 10% and 2% of the time, respectively. The criteria for baseflow conditions are calculated to satisfy the geometric mean water quality standard for the season. The numerical targets for these criteria are summarized in Table 6.1.

Table 6.1. TMDL Criteria

TMDL Criteria (Water Quality Targets)	TSS (mg/l)	TN (mg/l)	TP (mg/l)
Dry Season: Baseflow	8	0.155	0.026
10% Storm Event	30	0.380	0.060
2% Storm Event	55	0.600	0.080
Wet Season: Baseflow	16	0.209	0.042
10% Storm Event	50	0.520	0.100
2% Storm Event	80	0.800	0.150

Loading capacities and their allocations developed for baseflow conditions are geometric mean values not to be exceeded during the 86% and 80% of the dry season and wet season days, respectively, when seasonal baseflow conditions prevail. Loading capacities and allocations developed for the 10% storm events are intended as values to be exceeded no more than 10% of the time. Loading capacities and allocations developed for the 2% storm events are intended as values to be exceeded no more than 2% of the time. Associating the wet weather TMDLs with explicit (critical) rainfall conditions is intended to provide some design insight for TMDL implementing authorities.

6.2 Load Capacity Calculations

Load capacities were calculated for each Kapa'a Stream segment as the maximum pollutant loads (point discharges and dispersed inflows) that will meet the Table 6.1 water quality targets for each of the six TMDL conditions. These load capacities for the dry season conditions are tabulated in Table 6.2 and for the wet season conditions in Table 6.3.

Table 6.2. Dry Season Kapa'a Stream Load Capacities

Dry Season Baseflow

		Dispersed Sources		
Segment	Flow	TSS	TN	TP
	(cfs)	(kgd)	(kgd)	(kgd)
1	0.06	38	0.10	0.03
2	0.29	65	0.21	0.06
3	0.53	39	0.12	0.03
4	0.73	45	0.15	0.04
5	0.01	61	0.10	0.04
6	0.87	31	0.06	0.02
8	0.09	2	0.03	0.01
Totals:		281	0.78	0.23

Dry Season 10% Storm Event

		Dispersed Sources			Point Sources		
Segment	Flow	TSS	TN	TP	TSS	TN	TP
	(cfs)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
1	0.07	17	0.03	0.01	0	0	0
2	0.29	29	0.05	0.01	0	0	0
3	0.54	17	0.03	0.01	0	0.00	0.00
4	0.74	20	0.04	0.01	0	0.00	0.00
5	0.01	27	0.02	0.01	0	0	0
6	0.87	14	0.02	0.00	0	0.00	0.00
8	0	0	0	0	0	0.00	0.00
Totals:		126	0.18	0.05	0	0.00	0.00

Dry Season 2% Storm Event

		Dispersed Sources			Point Sources		
Segment	Flow	TSS	TN	TP	TSS	TN	TP
	(cfs)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
1	0.18	84	0.22	0.04	0	0	0
2	0.61	131	0.28	0.05	0	0	0
3	1.88	88	0.26	0.04	36.02	0.39	0.05
4	4.12	135	0.66	0.10	61.31	0.67	0.09
5	0.29	142	0.37	0.06	0	0	0
6	5.35	247	1.44	0.22	8.70	0.09	0.01
8	0.48	0	0	0	21.67	0.24	0.03
Totals:		828	3.23	0.51	127.71	1.39	0.19

Table 6.3. Wet Season Kapa'a Stream Load Capacities

Wet Season Baseflow

		Dispersed Sources		
Segment	Flow (cfs)	TSS (kgd)	TN (kgd)	TP (kgd)
1	0.08	78	0.16	0.05
2	0.38	133	0.34	0.10
3	0.71	80	0.19	0.06
4	0.98	94	0.24	0.07
5	0.02	122	0.15	0.07
6	1.17	63	0.10	0.04
8	0.11	4	0.06	0.01
Totals:		573	1.23	0.41

Wet Season 10% Storm Event

		Dispersed Sources			Point Sources		
Segment	Flow (cfs)	TSS (kg)	TN (kg)	TP (kg)	TSS (kg)	TN (kg)	TP (kg)
1	0.13	44	0.09	0.02	0	0	0
2	0.51	72	0.15	0.04	0	0	0
3	1.26	47	0.12	0.03	9	0.10	0.02
4	2.31	61	0.22	0.05	16	0.16	0.03
5	0.11	69	0.11	0.03	0	0	0
6	2.90	41	0.12	0.03	2	0.02	0.00
8	0	0	0	0	0	0	0
Totals:		333	0.80	0.21	27	0.28	0.05

Wet Season 2% Storm Event

		Dispersed Sources			Point Sources		
Segment	Flow (cfs)	TSS (kg)	TN (kg)	TP (kg)	TSS (kg)	TN (kg)	TP (kg)
1	0.42	274	1.11	0.24	0	0	0
2	1.24	372	1.04	0.25	0	0	0
3	4.09	291	1.27	0.27	241	2.41	0.45
4	10.13	625	4.36	0.86	462	4.62	0.87
5	0.79	488	2.13	0.46	0	0	0
6	14.58	5,598	12.79	4.56	208	2.08	0.39
8	3.10	0	0	0	379	3.79	0.71
Totals:		7,647	22.69	6.64	1,290	12.90	2.42

6.3 Allocation Calculations

The calculated load capacities for each stream segment were allocated to each of the tributary sub-basin sources (land use/land cover types) in proportion to the existing load from the source. Where the existing loads were less than the allocated load capacity, the assigned source allocation was the existing load. This approach was intended to conform to the non-degradation policy in Hawaii's water quality standards. These source allocations for the six TMDL conditions are presented in the following Tables 6.4 through 6.9. Allocations for baseflow conditions assume that baseflow pollutant loads are contributed virtually exclusively via groundwater, whereas the allocations for storm event conditions are based upon the predominance of surface water contributions to pollutant loading.

Table 6.4. Dry Season Baseflow Source Allocations

ALLOCATIONS

Dry Season Baseflow

Sub-basin	Land Use/Cover	TSS (kgd)	TN (kgd)	TP (kgd)
A	Forest/brush	15	0.10	0.03
A	Highway	1	0.01	0.00
B	Forest/brush	5	0.02	0.01
B	Quarry	57	0.19	0.05
B	Roads	1	0.00	0.00
C	Forest/brush	2	0.01	0.00
C	Highway	1	0.00	0.00
D	Eroded	4	0.02	0.00
D	Highway	0	0.00	0.00
E	Forest/brush	2	0.00	0.00
E	Industrial	1	0.00	0.00
E	Roads	2	0.00	0.00
E	Highway	1	0.00	0.00
F	Forest/brush	5	0.01	0.00
F	Landfill	19	0.07	0.02
F	Roads	1	0.00	0.00
G	Forest/brush	3	0.01	0.00
G	Industrial	21	0.05	0.01
G	Highway	0	0.00	0.00
H	Forest/brush	10	0.04	0.01
H	Landfill	8	0.04	0.01
H	Roads	1	0.00	0.00
I	Landfill	1	0.01	0.00
I	Roads	1	0.00	0.00
J	Forest/brush	2	0.01	0.00
J	Landfill	7	0.05	0.02
J	Highway	1	0.00	0.00
K	Landfill	6	0.10	0.04
K	Roads	0	0.00	0.00
L	Landfill	1	0.02	0.00
L	Industrial	1	0.02	0.00
L	Roads	0	0.00	0.00
	Totals:	180	0.78	0.23

Table 6.5. Dry Season Source Allocations for 10% Storm Event

ALLOCATIONS

Dry Weather Season		10% Storm Event	P =	0.35	inch	
Sub-basin	Land Use/Cover		TSS (kg)		TN (kg)	TP (kg)
A	Forest/brush		0		0.00	0.00
A	Highway		0		0.00	0.00
B	Forest/brush		0		0.00	0.00
B	Quarry		0		0.00	0.00
B	Roads		0		0.00	0.00
C	Forest/brush		0		0.00	0.00
C	Highway		0		0.00	0.00
D	Eroded		0		0.00	0.00
D	Highway		0		0.00	0.00
E	Forest/brush		0		0.00	0.00
E	Industrial		0		0.00	0.00
E	Roads		0		0.00	0.00
E	Highway		0		0.00	0.00
F	Forest/brush		0		0.00	0.00
F	Landfill		0		0.00	0.00
F	Roads		0		0.00	0.00
G	Forest/brush		0		0.00	0.00
G	Industrial		0		0.00	0.00
G	Highway		0		0.00	0.00
H	Forest/brush		0		0.00	0.00
H	Landfill		0		0.00	0.00
H	Roads		0		0.00	0.00
I	Landfill		0		0.00	0.00
I	Roads		0		0.00	0.00
J	Forest/brush		0		0.00	0.00
J	Landfill		0		0.00	0.00
J	Highway		0		0.00	0.00
K	Landfill		0		0.00	0.00
K	Roads		0		0.00	0.00
L	Landfill		0		0.00	0.00
L	Industrial		0		0.00	0.00
L	Roads		0		0.00	0.00
	Totals:		0		0.00	0.00

Table 6.6. Dry Season Source Allocations for 2% Storm Event

ALLOCATIONS

Dry Weather Season		2% Storm Event	P =	1.27	inch	
Sub-basin	Land Use/Cover		TSS (kg)		TN (kg)	TP (kg)
A	Forest/brush		0		0.00	0.00
A	Highway		20		0.20	0.04
B	Forest/brush		0		0.00	0.00
B	Quarry		0		0.00	0.00
B	Roads		0		0.00	0.00
C	Forest/brush		0		0.00	0.00
C	Highway		13		0.13	0.05
D	Eroded		36		0.38	0.05
D	Highway		0		0.01	0.00
E	Forest/brush		0		0.00	0.00
E	Industrial		14		0.06	0.00
E	Roads		51		0.11	0.03
E	Highway		11		0.08	0.01
F	Forest/brush		0		0.00	0.00
F	Landfill		61		0.66	0.08
F	Roads		0		0.01	0.01
G	Forest/brush		12		0.07	0.02
G	Industrial		119		0.56	0.06
G	Highway		4		0.03	0.01
H	Forest/brush		0		0.00	0.00
H	Landfill		0		0.00	0.00
H	Roads		0		0.00	0.00
I	Landfill		8		0.08	0.01
I	Roads		1		0.02	0.01
J	Forest/brush		0		0.00	0.00
J	Landfill		244		1.35	0.17
J	Highway		2		0.09	0.05
K	Landfill		141		0.36	0.06
K	Roads		1		0.01	0.01
L	Landfill		19		0.15	0.02
L	Industrial		2		0.08	0.01
L	Roads		0		0.01	0.00
	Totals:		760		4.45	0.70

Table 6.7. Wet Season Baseflow Source Allocations

ALLOCATIONS

Wet Weather Baseflow

Sub-basin	Land Use/Cover	TSS (kgd)	TN (kgd)	TP (kgd)
A	Forest/brush	19	0.15	0.05
A	Highway	1	0.01	0.00
B	Forest/brush	7	0.02	0.01
B	Quarry	83	0.30	0.08
B	Roads	1	0.00	0.00
C	Forest/brush	3	0.01	0.01
C	Highway	1	0.00	0.00
D	Eroded	5	0.03	0.01
D	Highway	0	0.00	0.00
E	Forest/brush	3	0.01	0.00
E	Industrial	2	0.00	0.00
E	Roads	2	0.00	0.00
E	Highway	1	0.00	0.00
F	Forest/brush	8	0.02	0.01
F	Landfill	28	0.11	0.04
F	Roads	2	0.00	0.00
G	Forest/brush	5	0.02	0.01
G	Industrial	30	0.07	0.01
G	Highway	1	0.00	0.00
H	Forest/brush	17	0.06	0.02
H	Landfill	15	0.07	0.03
H	Roads	1	0.00	0.00
I	Landfill	3	0.01	0.00
I	Roads	1	0.00	0.00
J	Forest/brush	4	0.02	0.01
J	Landfill	11	0.07	0.03
J	Highway	1	0.00	0.00
K	Landfill	10	0.14	0.07
K	Roads	1	0.00	0.00
L	Landfill	2	0.03	0.01
L	Industrial	3	0.03	0.00
L	Roads	0	0.00	0.00
	Totals:	269	1.23	0.41

Table 6.8. Wet Season Source Allocations for 10% Storm Event

ALLOCATIONS

Wet Weather Season — 10% Storm Event — P = 0.70 inch

Sub-basin	Land Use/Cover	TSS (kg)	TN (kg)	TP (kg)
A	Forest/brush	0	0.00	0.00
A	Highway	6	0.06	0.02
B	Forest/brush	0	0.00	0.00
B	Quarry	0	0.00	0.00
B	Roads	0	0.00	0.00
C	Forest/brush	0	0.00	0.00
C	Highway	4	0.04	0.04
D	Eroded	9	0.09	0.02
D	Highway	0	0.00	0.00
E	Forest/brush	0	0.00	0.00
E	Industrial	4	0.03	0.00
E	Roads	19	0.05	0.02
E	Highway	4	0.04	0.01
F	Forest/brush	0	0.00	0.00
F	Landfill	15	0.16	0.03
F	Roads	0	0.00	0.00
G	Forest/brush	1	0.00	0.00
G	Industrial	58	0.20	0.04
G	Highway	2	0.01	0.01
H	Forest/brush	0	0.00	0.00
H	Landfill	0	0.00	0.00
H	Roads	0	0.00	0.00
I	Landfill	2	0.02	0.00
I	Roads	0	0.01	0.00
J	Forest/brush	0	0.00	0.00
J	Landfill	40	0.10	0.02
J	Highway	1	0.01	0.01
K	Landfill	68	0.11	0.03
K	Roads	1	0.00	0.00
L	Landfill	0	0.00	0.00
L	Industrial	0	0.00	0.00
L	Roads	0	0.00	0.00
	Totals:	237	0.95	0.26

Table 6.9. Wet Season Source Allocations for 2% Storm Event

ALLOCATIONS				
Wet Weather Season	2% Storm Event	P = 2.30 inch		
Sub-basin	Land Use/Cover	TSS (kg)	TN (kg)	TP (kg)
A	Forest/brush	75	0.51	0.09
A	Highway	65	0.59	0.15
B	Forest/brush	0	0.00	0.00
B	Quarry	0	0.00	0.00
B	Roads	0	0.00	0.00
C	Forest/brush	12	0.09	0.03
C	Highway	49	0.49	0.22
D	Eroded	241	2.34	0.45
D	Highway	0	0.07	0.01
E	Forest/brush	17	0.11	0.02
E	Industrial	51	0.29	0.01
E	Roads	183	0.50	0.15
E	Highway	41	0.37	0.09
F	Forest/brush	1	0.06	0.03
F	Landfill	458	4.49	0.77
F	Roads	3	0.08	0.07
G	Forest/brush	132	1.05	0.40
G	Industrial	479	3.17	0.37
G	Highway	14	0.15	0.08
H	Forest/brush	1	0.07	0.02
H	Landfill	133	1.27	0.17
H	Roads	1	0.03	0.02
I	Landfill	66	0.60	0.08
I	Roads	6	0.12	0.09
J	Forest/brush	10	0.09	0.06
J	Landfill	5,545	9.30	2.33
J	Highway	43	0.55	0.55
K	Landfill	484	2.10	0.42
K	Roads	4	0.04	0.04
L	Landfill	338	2.47	0.44
L	Industrial	36	1.23	0.18
L	Roads	6	0.10	0.09
	Totals:	8,494	32.29	7.43

6.4 Margin of Safety

There are significant margins of safety implicit in the calculations of load capacities and their allocations. In the event-averaged streamflow and water quality calculations, for example, an estimated time of runoff concentration is included but stream segment travel (or retention) times are ignored. This results in a lesser calculated than likely actual time for sedimentation or other stream assimilation mechanism.

For another example, the critical 10% and 2% rainfall events were determined from the 24-hour days of recorded rainfall. However, the actual durations of rainfall, runoff, increased streamflow and pollutant loadings are for all the thus-determined events less than a full 24 hours, usually significantly less. The actual times of exceeding the respective 10% and 2% water quality criteria are thereby substantially less (40 to 80%) than assumed.

Finally, the assignment of existing loads as allocations instead of load capacity based allocations where the existing sub-basin load is less than the individual segment load capacity provides large margins of safety for the total watershed TMDLs.

6.5 Consolidation of Sources

To complete the load allocation process required for TMDL approval and implementation, load source categories and their allocations are consolidated into:

- loads from and allocations to areas that include facilities that are regulated or should be regulated by National Pollutant Discharge Elimination System (NPDES) permits, and
- loads from and allocations to remaining areas that don't include any NPDES-regulated facilities.

Although there is some uncertainty about the occurrence and extent of co-mingling of storm runoff among these regulated and non-regulated areas, it is likely that this uncertainty will be resolved in the near future due to the greater emphasis on inventorying system infrastructure that is appearing in the new generation of NPDES permits and recent enforcement case settlement agreements.

The Kapa'a Quarry access road and its immediate tributary drainage area are included in the City & County of Honolulu (CCH) Municipal Separate Storm Sewer System (MS4) NPDES facility area. This is represented by the road area in Sub-basins E and K and all of Sub-basin I. The CCH Kalaheo landfill and tributary facility area is represented by Sub-basin H. The CCH Kapa'a landfill facility area is represented by Sub-basin F and the landfill area in Sub-basin L. The CCH refuse transfer station and baseyard facility areas are represented by the consolidation of industrial and road areas in Sub-basin L. The facility area for the State of Hawaii Department of Transportation (DOT) Highways Division MS4 permit is represented by the consolidation of all highway areas in Sub-basins A, C, D, E, G, and J. The facility area for the Ameron Quarry industrial stormwater permit is all of Sub-basin B. The collection of business and industrial activities within the John T. King property is collectively represented by the industrial facility areas in Sub-basins E and G.

All of these facility areas are assumed to contribute (via infiltration and percolation) to the groundwater that provides the baseflow of Kapaa stream. Thus the facility areas described above are all considered as nonpoint sources of baseflow volume and quality and are assigned nonpoint source load allocations ("LAs to facility areas" in Tables 6.10. and 6.11.) for baseflow conditions only. The remaining nonpoint source area for both baseflow and storm event conditions (no NPDES-regulated facilities) is the consolidation of forest/brush and eroded areas in Sub-basins A, C, D, E, G, and J and the landfill areas in Sub-basins J and K that are not within the NPDE-regulated service area.

Consolidations of existing dry season loads, TMDL allocations, and reductions required are presented in Table 6.10. The same consolidations for wet season conditions are displayed in Table 6.11. Implementation of the required load reductions will result in attainment of the water quality standards for total suspended solids, total nitrogen, and total phosphorus in Kapa’a Stream.

Table 6.10. Consolidated Dry Season TMDL Allocations to Existing Sources*
and
Load Reductions Required to Achieve Kapaa Stream TMDLs

Dry Season Baseflow	**TMDLs**			**Existing Loads**			**Reductions Required**					
	TSS	**TN**	**TP**	**TSS**	**TN**	**TP**	**TSS**		**TN**		**TP**	
LAs to facility areas	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	*(%)*	(kgd)	*(%)*	(kgd)	*(%)*
CCH MS4	5	0.0	0.0	5	0.1	0.0	1	11	0.1	83	0.0	85
CCH Kalaheo Landfill	19	0.1	0.0	24	0.5	0.2	5	20	0.5	85	0.2	87
CCH Kapa'a Landfill	27	0.1	0.0	36	0.9	0.3	9	25	0.8	89	0.3	91
CCH Waste Transfer	1	0.0	0.0	23	0.3	0.1	22	95	0.3	94	0.1	96
HI DOT Highways MS4	4	0.0	0.0	4	0.1	0.0	0	4	0.1	79	0.0	81
Ameron Quarry	62	0.2	0.1	69	1.4	0.3	7	10	1.2	85	0.2	81
Industrial Park	22	0.1	0.0	28	0.4	0.1	5	19	0.3	85	0.1	87
LA to other source areas	40	0.3	0.1	41	1.0	0.4	1	2	0.7	70	0.3	71
Totals	**180**	**0.8**	**0.2**	**229**	**4.6**	**1.4**	**49**	***21***	**3.9**	***83***	**1.2**	***83***

Dry Season 10% Runoff	**TMDLs**			**Existing Loads**			**Reductions Required**					
	TSS	**TN**	**TP**	**TSS**	**TN**	**TP**	**TSS**		**TN**		**TP**	
WLAs	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	*(%)*	(kg)	*(%)*	(kg)	*(%)*
CCH MS4	0.1	0.0	0.0	0.1	0.0	0.0	0.0	13	0.0	10	0.0	13
CCH Kalaheo Landfill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0
CCH Kapa'a Landfill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0
CCH Waste Transfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0
HIDOT Highways MS4	0.2	0.0	0.0	0.3	0.0	0.0	0.0	5	0.0	4	0.0	6
Ameron Quarry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0
Industrial Park	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0
LA to Nonpoint sources	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0
Totals	**0.3**	**0.0**	**0.0**	**0.4**	**0.0**	**0.0**	**0.0**	***7***	**0.0**	***5***	**0.0**	***7.2***

Dry Season 2% Runoff	**TMDLs**			**Existing Loads**			**Reductions Required**					
	TSS	**TN**	**TP**	**TSS**	**TN**	**TP**	**TSS**		**TN**		**TP**	
WLAs	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	*(%)*	(kg)	*(%)*	(kg)	*(%)*
CCH MS4	61	0.2	0.1	384	0.7	0.5	323	84	0.5	68	0.4	90
CCH Kalaheo Landfill	0	0.0	0.0	0	0.0	0.0	0	0	0.0	0	0.0	0
CCH Kapa'a Landfill	80	0.8	0.1	3586	4.9	1.3	3506	98	4.0	83	1.2	92
CCH Waste Transfer	3	0.1	0.0	49	0.3	0.1	46	95	0.2	71	0.1	85
HIDOT Highways MS4	49	0.5	0.2	68	0.7	0.7	19	28	0.2	22	0.5	76
Ameron Quarry	0	0.0	0.0	0	0.0	0.0	0	0	0.0	0	0.0	0
Industrial Park	133	0.6	0.1	272	1.7	0.3	139	51	1.1	63	0.3	82
LA to Nonpoint sources	434	2.2	0.3	8545	5.0	3.5	8111	95	2.9	57	3.2	91
Totals	**760**	**4.5**	**0.7**	**12904**	**13.3**	**6.3**	**12144**	***94***	**8.8**	***66***	**5.7**	***89***

*TMDL allocations in kg/day are obtained by dividing dry season kg by 184 days.
Loads and Load Reductions are rounded to the nearest 0.1 kg, thus (a) **Totals** may be different than the sum of their parts and (b) **TMDLs**, **Existing Loads** and **Reductions Required** may actually be greater than 0.

<u>Acronyms</u>
TMDLs = Total Maximum Daily Loads
LAs = Load Allocations
WLAs = Waste Load Allocations
kgd = kilograms per day
TSS = Total Suspended Solids
TN = Total Nitrogen
TP = Total Phosphorous
CCH = City and County of Honolulu
MS4 = Municipal Separate Storm Sewer System
HIDOT = State of Hawaii Department of Transportation
kg = kilograms

Table 6.11. Consolidated Wet Season TMDL Allocations to Existing Sources
and
Load Reductions Required to Achieve Kapaa Stream TMDLs

Wet Season Baseflow	TMDLs			Existing Loads			Reductions Required					
	TSS	TN	TP	TSS	TN	TP	TSS		TN		TP	
LAs to facility areas	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	*(%)*	(kgd)	*(%)*	(kgd)	*(%)*
CCH MS4	7	0.0	0.0	7	0.1	0.0	0	0	0.1	81	0.0	82
CCH Kalaheo Landfill	34	0.1	0.1	34	0.8	0.3	0	0	0.6	82	0.3	83
CCH Kapa'a Landfill	39	0.2	0.1	52	1.3	0.5	13	25	1.2	87	0.4	88
CCH Waste Transfer	3	0.0	0.0	27	0.4	0.1	24	89	0.3	92	0.3	95
HI DOT Highways MS4	5	0.0	0.0	5	0.1	0.0	0	0	0.1	76	0.0	76
Ameron Quarry	91	0.3	0.1	91	1.2	0.4	0	0	1.5	82	0.3	75
Industrial Park*	31	0.1	0.0	31	0.4	0.1	0	0	0.4	82	0.1	83
LA to other source areas	59	0.5	0.2	59	1.4	0.5	0	0	1.0	69	0.3	66
Totals	**269**	**1.2**	**0.4**	**306**	**6.3**	**1.9**	**37**	***12***	**5.1**	***81***	**1.5**	***79***
Wet Season 10% Runoff	**TMDLs**			**Existing Loads**			**Reductions Required**					
	TSS	**TN**	**TP**	**TSS**	**TN**	**TP**	**TSS**		**TN**		**TP**	
WLAs	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	*(%)*	(kg)	*(%)*	(kgd)	*(%)*
CCH MS4	22	0.1	0.0	113	0.2	0.2	91	80	0.1	61	0.1	83
CCH Kalaheo Landfill	0	0.0	0.0	0	0.0	0.0	0	0	0.0	0	0.0	0
CCH Kapa'a Landfill	16	0.2	0.0	902	1.2	0.3	886	98	1.1	87	0.3	90
CCH Waste Transfer	0	0.0	0.0	0	0.0	0.0	0	0	0.0	0	0.0	0
HIDOT Highways MS4	17	0.2	0.1	23	0.2	0.2	6	27	0.1	28	0.1	60
Ameron Quarry	0	0.0	0.0	0	0.0	0.0	0	0	0.0	0	0.0	0
Industrial Park*	63	0.2	0.0	89	0.6	0.1	26	29	0.3	59	0.1	65
LA to Nonpoint sources	119	0.3	0.1	2252	1.2	0.9	2134	95	0. 9	74	0.8	92
Totals	**237**	**1.0**	**0.3**	**3379**	**3.4**	**1.7**	**3142**	***93***	**2. 5**	***72***	**1.5**	***85***
Wet Season 2% Runoff	**TMDLs**			**Existing Loads**			**Reductions Required**					
	TSS	**TN**	**TP**	**TSS**	**TN**	**TP**	**TSS**		**TN**		**TP**	
WLAs	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	*(%)*	(kg)	*(%)*	(kg)	*(%)*
CCH MS4	258	1.3	0.4	1926	3.2	2.1	1668	87	2.0	61	1.7	83
CCH Kalaheo Landfill	136	1.4	0.2	3154	4.6	1.3	3018	96	3.3	71	1.1	84
CCH Kapa'a Landfill	800	7.1	1.3	22726	30.9	8.2	21926	96	23.8	77	6.9	84
CCH Waste Transfer	42	1.3	0.3	806	4.8	1.3	765	95	3.4	72	1.1	80
HIDOT Highways MS4	212	2.2	1.1	268	2.7	2.7	56	21	0.5	17	1.6	59
Ameron Quarry	0	0.0	0.0	0	0.0	0.0	0	0	0.0	0	0.0	0
Industrial Park*	530	3.5	0.4	1239	7.8	1.6	710	57	4.3	55	1.2	75
LA to Nonpoint sources	6516	15.6	3.8	41164	27.3	18.2	34648	84	11.7	43	14.4	79
Totals	**8494**	**323**	**7.4**	**71284**	**81.2**	**35.4**	**62790**	***88***	**48.9**	***60***	**28.0**	***79***

*TMDL allocations in kg/day are obtained by dividing wet season kg by 181 days.
Loads and Load Reductions rounded to the nearest 0.1 kg, thus (a) **Totals** may be different than the sum of their parts and (b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.
Acronyms – see previous dry season table

6.6 Implementation Assurance

Wasteload allocations (WLAs) for the Kapa'a Stream TMDLs will be implemented through compliance with NPDES permit conditions and by following the stormwater management plans associated with those permits (Table 6.12). It will be necessary to revise most of these permits to include effluent limitations consistent with the approved WLAs, as required by federal regulations at 40 CFR 122.44 (d)(1).

Table 6.12. NPDES Permits controlling discharges to Kapa'a Stream

Permit Type[1]	Permittee/Facility	Permit Number	Issued / Expires	Plan Dates[2]	Date of Last Inspection	Date of Last Violation[3]	Discharge Monitoring Required?[4]
Phase 1 MS4	State of Hawaii Department of Transportation, Highways Division/MS4	HI S000001	02/28/2006 09/08/2009	SWMP due 03/31/2007	09/22/2004	10/10/2000 NAV	No
Phase 1 MS4	City & County of Honolulu, Departments of Environmental Services, Facilities Maintenance, Design & Construction, Planning & Permitting/MS4	HI S000002	02/28/2006 09/08/2009	SWMP due 03/31/2007	09/22/2004		No
I-MAJ	Ameron Hawaii/Kapaa Quarry	HI 0020796	10/03/2006 03/31/2010	BMPP due 11/03/2006	11/19/2003	08/23/2000[3a] NAV	R, M
I-MIN	City & County of Honolulu, Department of Environmental Services/Kapaa Sanitary Landfill and Transfer Station[6]	HI 0021563	8/2/2002 12/31/2006	SWPCP due 12/02/2002			Yes
NGPC-B	City & County of Honolulu, Department of Environmental Services/Kalaheo Landfill	HI R50A532	4/15/2005 11/06/2007	Revised SWPCP due 08/15/2005	05/23/2000		No
NGPC-B	Industrial Park tenants						
NGPC	Various	Various	Various	na[5]	na[5]		na[5]
I-MIN	Hawaiian Earth Products/Windward green waste recycling[7]	HI 0021801	10/18/2005 09/30/2010	BMPP dated 08/16/2004 & 08/05/2005			No
Phase 2 MS4	City & County of Honolulu, Department of Facilities Maintenance/Kapaa Corporation Yard[7]	HI S000077	pending				

[1]Key to Permit Types:
MS4 = Municipal Separate Storm Sewer System (Phase 1 = large, Phase 2 = Small)
NGPC = Notice of General Permit Coverage (Appendices B-L)
B = Industrial Stormwater
I = Individual
MAJ = Major
MIN = Minor

[2]Key to Plan Types
SWMP = Storm Water Management Plan
BMPP = Best Management Practices Plan
SWPCP = Storm Water Pollution Control Plan

[3]Key to ViolationTypes
NAV = Notice of Apparent Violation
[3a]NFV & O = Notice and Finding of Violation and Order, 08/21/2000 and other previous dates

[4]Key to Discharge Monitoring Requirements (for discharges to Kapa'a Stream):
N = None
R = Report occurrence of discharge
M = Report measurements of discharge constituents

[5]na = not generally applicable to these kinds of permits

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[6]This facility also discharges to Kawainui Marsh (the receiving water for Kapaa Stream) and will be assigned WLAs by future Kawainui Marsh TMDLs.

[7]This facility discharges to Kawainui Marsh (the receiving water for Kapaa Stream). Although this facility isn't assigned Waste Load Allocations (WLAs) for the Kapa'a Stream TMDLs, it is included here for informational purposes, and will be assigned WLAs by future Kawainui Marsh TMDLs.

The large MS4 NPDES permits recently reissued to the City & County of Honolulu (CCH MS4) and State of Hawaii Department of Transportation Highways Division (HIDOT) require the respective permittees to develop WLA implementation and monitoring plans for at least one newly approved TMDL submittal per year. Given the protected and prominent status of the Kapa'a Stream receiving waters (Kawainui Marsh) and the magnitude of government and community resources already dedicated to repairing and managing these wetlands, we hope that the permittees will address each of the WLAs in Tables 6.10 and 6.11 above within one year of the approval date of the TMDLs. These WLA implementation plans shall identify specific actions targeted to achieving the needed reductions of total suspended solids, total nitrogen, and total phosphorus. The WLA monitoring plans shall specify the water quality monitoring and activity tracking necessary to demonstrate compliance with the WLAs assigned to the permittees.

Other NPDES permits that regulate discharges to Kapaa Stream (Table 6.12) must be revised to incorporate provisions consistent with the WLAs. Similar to the MS4 permits discussed above, these revisions will incorporate requirements that permittees submit for DOH approval, in accordance with a specified schedule, specific implementation and monitoring plans sufficient to implement the specific WLAs, and that the permittees will then be required to promptly implement these plans.

Wasteload allocations to the City & County of Honolulu landfills will be implemented through the NPDES individual permit (No. HI 0021563) for the Kapaa Landfill area and NPDES general permit coverage (NGPC No. HI R50A532) for the Kalaheo Landfill area. Although the Kapaa Refuse Transfer Station is assigned a separate WLA, its NPDES permit coverage (and WLA implementation responsibility) has been merged with the Kapaa Landfill NPDES permit.

Implementation of WLAs to the City & County of Honolulu Kapaa Corporation Yard will be assisted by the submittal of information and development of stormwater management plans for municipal industrial facilities that are required under NPDES Phase II small facility stormwater discharge permits (small MS4). All public facilities on Oahu with more than one building and an underground drainage system (as indicated by an inlet/outlet that leads to/from a subsurface conveyance structure) are required to apply for permit coverage, and the City Department of Facilities Maintenance application for a facility-wide permit was recently submitted to the State of Hawaii Department of Health. However, the City is still considering the option of adding all these facilities to its existing large MS4 permit coverage (Wakumoto 2006).

Wasteload allocations to the Ameron Hawaii Quarry will be implemented through the NPDES permit (No. HI 0020796) for the quarry. That existing permit requires that the "volume of process waste waters and storm water which would result from a 10-year, 24-hour rainfall event" shall be contained or treated on-site. The zero discharge WLAs for the 10% and 2% rainfall events in Tables 6.10 and 6.11 are thus already requirements of the existing NPDES permit for the quarry. However, ongoing concerns about the impact of more extreme rainfall events and permitted quarry discharges upon downslope land areas and receiving waters warrant additional water pollution control and water quality management attention (see below).

WLAs to the industrial park in Sub-basin G will be implemented through NPDES permits for the individual businesses in facilities leased from the business park landowner (John T. King's Kapaa 1, LLC). At this time, only those businesses with qualifying standard industrial operations that are directly exposed to rainfall are required to apply for NPDES industrial stormwater discharge permits. Remaining areas of the industrial park area are considered as a nonpoint source of pollutants not subject to NPDES permit. The industrial park area as a whole is encouraged to participate in the DOH Polluted Runoff Control Program (Clean Water Branch) and to reassess and modify its drainage plans. Changing the State's NPDES permitting scheme for discharges of industrial stormwater in ways that expand permit coverage for areas like this is another implementation option to be considered.

Load Allocations (LAs) -The nonpoint source load allocations (LAs) for the Kapa’a watershed area may be implemented through a variety of voluntary approaches to polluted runoff control, including those described in Hawaii’s Implementation Plan for Polluted Runoff Control (Coastal Zone Management Program and Polluted Runoff Control Program, 2000), Hawaii’s Coastal Nonpoint Pollution Control Program (Hawaii Coastal Zone Management Program, 1996). Both these plans are being updated and revised to better address, among other objectives, implementation of TMDL allocations.

Specific measures for reducing pollutant loads in the Kapa’a watershed are identified in the Ko’olaupoko Water Quality Action Plan (Kailua Bay Advisory Council, 2002) and the Kailua Waterways Improvement Plan, Strategic Implementation Plan, and BMP Manual (Tetra Tech EM, Inc., 2003). They will also be a focus of future watershed-based plans and TMDL implementation plans (State of Hawaii Department of Health). By addressing the nine elements required by EPA guidance and incorporating the LA objectives from Tables 6.10 and 6.11 above, these plans can unlock the door to additional Clean Water Act §319(h) incremental funds for water quality improvement projects. Such projects may also qualify for the DOH Clean Water State Revolving Fund Program, which provides low interest loans for the construction of point source and non-point source water pollution control projects.

One intriguing approach to achieving the Kapa’a Stream water quality targets for baseflow conditions is augmentation of the dry weather streamflow with a source of high quality water. The increased flow would increase the baseflow load capacity and respective nonpoint source load allocations. Ameron’s main quarry floor pit (Pond D) is a potential streamflow augmentation source that might provide as much as 1 cfs of relatively high quality flow during non-rainfall baseflow periods, and the controlled discharge from this pond would increase its stormflow storage capacity (Goldstein 2005). This approach appears to deserve further analysis in the context of overall Kawainui Marsh management goals and available mechanisms for modifying Ameron’s current NPDES permit. Ameron's current NPDES permit, written to conform with federal regulations for permit conditions associated with industrial mining, does not allow any discharge except when rainfall exceeds the 10-year, 24-hour event.

Future Kawainui Marsh management planning may also benefit from additional attention to the effects of wet weather loading from the quarry and landfills during extreme events and to the constant flux of quarry and landfill-influenced groundwater. While the status of landfill environmental management is partially settled (Curnow, 2006), ongoing attention to groundwater and leachate monitoring and landfill/marsh hydrology appears to be warranted based on historic data (The Environmental Company, Inc., 2005; Earth Tech, Inc., 2001; Barrett Consulting Group, Inc. 1996) and related precautions and prudence.

Chapter 7
Public Participation

During the TMDL development process, EPO staff discussed the TMDLs with various interested parties and sources of information, including:

State of Hawaii Department of Health (Environmental Health Analytical Services Branch, Clean Water Branch, Solid and Hazardous Waste Branch, Hazard Evaluation and Emergency Response Office, Clean Air Branch)
State of Hawaii Department of Transportation (Highways Division)
State of Hawaii Department of Business, Economic Development, & Tourism
City & County of Honolulu (Department of Environmental Services, Board of Water Supply, Kailua Neighborhood Board)
U.S. Environmental Protection Agency

Ameron, Inc.
John King
Kailua Bay Advisory Council
Kaneohe Ranch
Oceanit, Inc.
Tetra Tech EM, Inc.
Weston Solutions, Inc.
Windward Ahupua'a Alliance

Related environmental concerns (particularly Ameron Quarry NPDES permitting, dust from quarry operations, H3 stormwater management, development of the industrial park, and trash and illegal dumping along the roadways and waterways) have been the focus of ongoing participation by the Kailua Neighborhood Board, Kailua Bay Advisory Council, and Windward Ahupua'a Alliance with various Department of Health programs.

This TMDL technical report is the subject of a public notice and is distributed for public review, with direct notice to interested parties. A public information meeting will be held on November 15, 2006 to present and discuss the results. The deadline for receipt of public reviews by the Department of Health is December 06, 2006. After that date, a consolidated response to public comments will be mailed out to each commenter. The public meeting results, public comments, and response to comments will be incorporated in the final edition of the TMDL technical report, which will be submitted, along with supporting materials, for EPA approval.

Total Maximum Daily Loads of Total Suspended Solids, Nitrogen and Phosphorus
For Kapa'a Stream, Kailua, Hawaii
TECHNICAL APPENDIX

A.1.0 Purpose.

The TMDL allocation process needs to disaggregate watershed-scale observations of stream flow and stream quality to contributions from individual sub-basins in the watershed and from identified land use areas, i.e., pollutant sources, in each sub-basin during both dry weather and wet weather conditions. The elements of a systematic and technically consistent procedure for this disaggregation in the Kapa'a Stream watershed are described in this Appendix.

A.2.0 Rainfall Distribution.

Local climatic patterns are influenced by a number of local factors: topography, terrain features, and proximity to coastal moisture sources. The climatic statistical regression model known as PRISM (parameter–elevation regressions on independent slopes model) incorporates these factors in a GIS-based climatic mapping system developed at Oregon State University for USDA-NRCS and other agencies (Daly et al, 2002). PRISM climatic mapping has now been extended by NRCS to all of the U.S. states including the islands of Hawaii. This system provides 30-year (1961-1990) statistical regressions of annual and mean monthly rainfall distributions at 500m x 500m grid cell resolution for Oahu, including the Kapa'a watershed area. Seasonal distributions are obtained from summations of May-October (dry season) and November-April (wet season) monthly rainfall values. If temporal rainfall distributions are assumed similar across small watershed areas, then spatial distributions of rainfall for an individual event, e.g., 10% or 2% frequency storm, can be approximated:

$$P_j = \frac{P_{Zj}}{P_{ZR}} P_R \qquad (2\text{-}1)$$

Where:

P_j = event rainfall at watershed location j
P_{Zj} = seasonal PRISM rainfall at location j
P_{ZR} = seasonal PRISM rainfall at reference location
P_R = event rainfall at reference location in or near watershed area.

A.3.0 Evaporation.

Pan-evaporation data from Hawaii have been correlated inversely with annual rainfall (Takasaki et al, 1969). Rainfall can evidently be an effective surrogate for a combination of parameters (solar incidence, vapor pressure, cloud cover) normally found in calculations of evaporation and evapotranspiration. The form of the regression equation developed by Takasaki et al, $\log_{10}E = 1.9387 - 0.0035P$, is computationally awkward for

TMDL disaggregation purposes. Figure A1 is a replotting of the Oahu evaporation data from Takasaki et al (Table 4) in a more convenient linear form. The regression equation (r^2 = 0.948) for the evaporation data in this form is:

$$E_v = 78.39 - 0.341P \qquad (3\text{-}1)$$

Where:

E_v = median annual pan evaporation, inch
P = median annual precipitation, inch

Baseflow data for Kawa Stream (see section A.5.0) indicates that equation *3-1*, or at least its intercept, 78.39, may overstate actual evapotranspiration rates. Evapotranspiration, at least during conditions of limited soil moisture, is likely to be less than pan evaporation measurements.

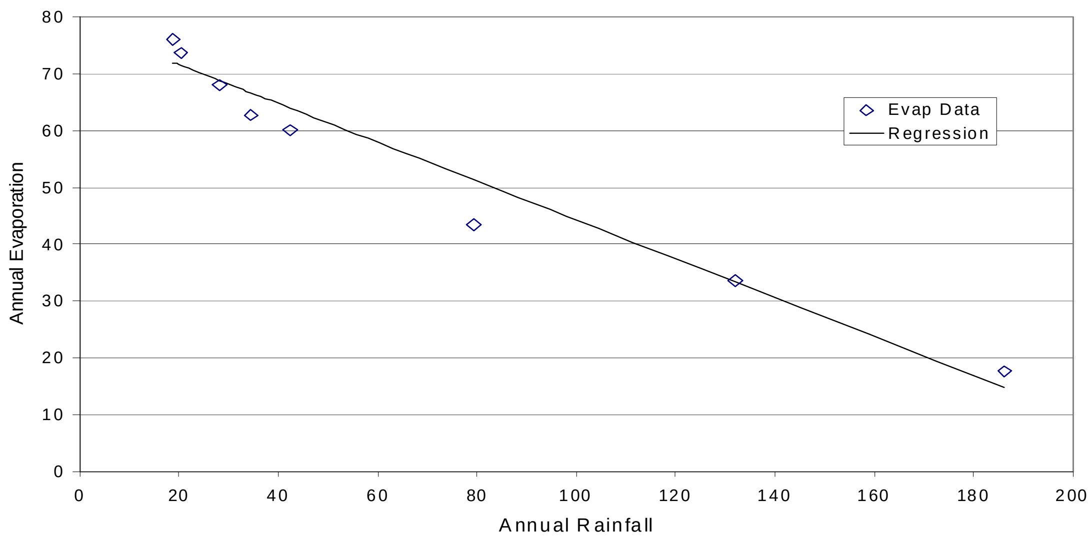

Figure A1. Correlation of Evaporation with Rainfall, Oahu Stations

A.4.0 Stormwater Runoff.

Of the several approaches used to simulate stormwater runoff, two relatively simple models are useful for the scale and purposes of TMDL development. For individual events, i.e., design storms, the SCS runoff formulation (USDA 1985, 1986) has found wide application:

$$R = \frac{(P - 0.2S)^2}{(P - 0.2S) + S} \qquad (4\text{-}1a)$$

$$S = \frac{1000}{CN} - 10 \qquad (4\text{-}1b)$$

Where:

R = event runoff, inch
P = event rainfall, inch
S = potential maximum retention after runoff begins, inch
CN = SCS curve number, $0 < CN < 100$.

The major factors that determine *CN* are the hydrologic soil group (*HSG*), land use, cover, and conservation practice. *CN* values are tabulated in the referenced TR-55 (USDA 1986). *HSG* classifications (Table K1) for Hawaii soils, along with detailed soil maps and other information, can be found in NRCS soil survey reports (http://www.ctahr.hawaii.edu/soilsurvey/soils.htm).

The runoff volume (ft^3) contributed by an individual land use parcel *j* is:

$$(V_R)_j = \frac{43{,}560}{12} \frac{\left(P_R \frac{P_{Zj}}{P_{ZR}} - 0.2S_j\right)^2}{P_R \frac{P_{Zj}}{P_{ZR}} + 0.8S_j} A_j \qquad (4\text{-}2)$$

For multiple event periods, e.g., seasonal or annual, a rational formula runoff expression has been commonly used. Estimates of annual pollutant loads in the Honolulu City & County MS4 permit application (CCH 1992) are based on such a runoff expression:

$$R = (P)(p_r)(R_v) \qquad (4\text{-}3a)$$

$$R_v = 0.05(1-f_I) + 0.95f_I \qquad (4\text{-}3b)$$

Where:

p_r = fraction of rainfall that produces runoff (0.9 used by Honolulu)
R_v = mean runoff coefficient
f_I = impervious fraction of area.

Equation *4-3b* considers the impervious fraction to flow directly to the storm sewer drainage system. Where not all of the impervious area is connected to a storm sewer system, i.e., some of the impervious area runoff is directed to pervious areas and infiltrates, the runoff coefficient expression can include a connected area fraction term, f_C, and:

$$R_v = 0.05(1-f_I) + (0.05)(0.95)f_I(1-f_C) + 0.95f_If_C \qquad (4\text{-}3c)$$

$$= 0.05 - (0.05)^2 f_I + (0.95)^2 f_I f_C$$

In the application of equation *4-3*, P is the mean annual or seasonal rainfall and R is the corresponding mean annual or seasonal runoff.

The runoff volume (ft^3) contributed by an individual land use parcel j is:

$$(V_R)_j = \frac{43{,}560}{12} P_R \frac{P_{Zj}}{P_{ZR}} (p_r R_v)_j A_j \qquad (4\text{-}4)$$

For either runoff expression, the load (kg) of pollutant k in the runoff from land parcel j is:

$$L_{jk} = \frac{28.32}{10^6} (V_R)_j C_{jk} \qquad (4\text{-}5)$$

Where:

C_{jk} = concentration of pollutant k in runoff from land use category j, mg/l.

A.5.0 <u>Stream Baseflow</u>.

A water balance developed for watershed soils connected hydraulically to the watershed surface streams will include recharge of soil water storage by infiltration (I) from rainfall events (and irrigation of agricultural soils) and depletion of the storage by evapotranspiration (E), other losses by percolation to underlying aquifers or at the watershed boundaries (L), and baseflow seepage to the watershed streams (Q_B). The dynamics of a monthly water balance is expressed.

$$\frac{\partial S_G}{\partial t} = (I - E - L)A - Q_B \qquad (5\text{-}1)$$

Where:

S_G = soil water storage, acre-inch
I = monthly infiltration, inch/month
E = monthly evapotranspiration, inch/month
L = other losses, inch/month
A = watershed area, acres
Q_B = monthly baseflow volume, acre-inch/month

Infiltration and evapotranspiration are obviously connected to the pervious area of the watershed. Other water storage losses may not be so directly connected, but can certainly be expressed as a function of the pervious area.

Baseflow can be related to available soil water storage through a recession coefficient:

$$\alpha \equiv \frac{\partial Q_B}{\partial S_G} \qquad (5\text{-}2)$$

Net infiltration over a period of rainfall events can be related through equation *4-3* to the total rainfall for the period.

$$I = [(1 - 0.05p_r)(1 - 0.05f_I) - (0.95)^2 p_r f_I f_C]P \qquad (5\text{-}3)$$

$$= [0.955 - 0.048f_I - 0.812f_I f_C]P$$

The above three equations can be combined to provide a dynamic baseflow function expressed in largely determinable terms of weather.

$$\frac{1}{\alpha}\frac{\partial Q_B}{\partial t} + Q_B = \{(0.955 - 0.048 f_I - 0.812 f_I f_C)P - (E+L)(1-f_I)\}A \qquad (5\text{-}4)$$

Where:

α = baseflow recession coefficient, month^{-1}
P = monthly rainfall, inch/month

The recession coefficient (α) is a technical function encompassing soil or aquifer hydraulic properties and watershed topography, stream density, and geology. A calculation of this recession coefficient may be developed from an appropriate expression of these watershed properties, i.e., through a mechanistic groundwater baseflow model. Alternatively, an operational value of the coefficient may be developed empirically, from available dry weather streamflow data, without committing to any particular groundwater model or mechanism beyond the thermodynamic demand of the water balance.

The integrated form of equation *5-4* expresses current baseflow in terms of its history.

$$(Q_B)_t = (Q_B)_0 \exp(-\alpha\Delta t) + A[(0.955 - 0.048 f_I - 0.812 f_I f_C)P - (E+L)(1-f_I)]_{\Delta t}[1 - \exp(-\alpha\Delta t)]d \qquad (5\text{-}5a)$$

or

$$(Q_B)_t = (Q_B)_0(1-a) + a\,d[bP - c]_{\Delta t} \qquad (5\text{-}5b)$$

For monthly mean flow, $$(\overline{Q}_B)_{\Delta t} \cong (\overline{Q}_B)_0(1-a) + a\,d[bP - c]_{\Delta t} \qquad (5\text{-}5c)$$

Where:

a = $[1 - \exp(-\alpha\Delta t)]$, if $\alpha\Delta t < 0.2$, $a \approx \alpha\Delta t$
b = $A[(0.955+e_v)-(0.048+e_v)f_I - 0.812f_I f_C]$
c = $A(1 - f_I)(E_0 + L)$
d = units conversion to cfs, (43,560/12)/(30x86,400) = 1.4 x 10^{-3}.

The relative contribution to the watershed or sub-basin area baseflow from an individual land use parcel *j* can be approximated through the *bP–c* term in equation (*5-5b*).

Combining equations *2-1* and *3-1* with *5-5* (and ignoring losses, *L*, e.g., percolation to underlying freshwater lens) yields the monthly *bP–c* expression for the individual land use parcel:

$$(bP-c)_j = \left(P_R \frac{P_{Zj}}{P_{ZR}} (1.296 - 0.389 f_I - 0.812 f_I f_C) - \frac{78.39}{12}(1 - f_I) \right) A_j \qquad (5\text{-}6a)$$

This expresses *bP-c* in units of acre-inch/month and includes the Honolulu City & County value of 0.9 for the runoff parameter p_r . The individual parcel $d(bP\text{-}c)_j$ in units of cfs will be:

$$d(bP-c)_j = \frac{A_j}{714} \left(P_R \frac{P_{Zj}}{P_{ZR}} (1.296 - 0.389 f_I - 0.812 f_I f_C) - 6.53(1 - f_I) \right) \qquad (5\text{-}6b)$$

This baseflow model was empirically tested against available rainfall and streamflow data from the adjacent Kawa Stream watershed. A regression-analysis fit of 1997-98 monthly mean baseflow measurements for Kawa Stream (Nance 1999) with initial monthly baseflow and contemporaneous local rainfall data (Kaneohe station 838.1) is shown in Figure A2. The regression equation in this figure,

$$Q_M = (0.781)Q_0 + (0.135)P - (0.223), \qquad r^2 = 0.956,$$

corresponds to values of 0.22, 0.76, and 1.25 for the parameters *a*, *b*, and *c*, respectively, in equation *5-5c*, with 723 acres and 0.20 effective impervious fraction in the watershed area tributary to Nance's upper streamflow monitoring gauge. The regression value for *b* in this regression analysis is only about half the theoretically derived *b*-value in equation *5-6* and the value for *c* is only about 1/5 the theoretical pan evaporation-based *c*-value. This may be because 1998 was a very dry rainfall-year and pan evaporation may overstate the evapotranspiration losses under extended dry soil conditions. The empirical regression coefficients can be reproduced if actual evapotranspiration, *E*, is assumed to be 27% of the equation *3-1* pan evaporation and the other losses in equation *5-1* are 32% of the resulting *I-E*. For the 30-year weather record considered in the Kapa'a Stream TMDL analysis, the longer-term equation *3-1* parameters are reduced by one-third and other losses are assumed to be 50%.

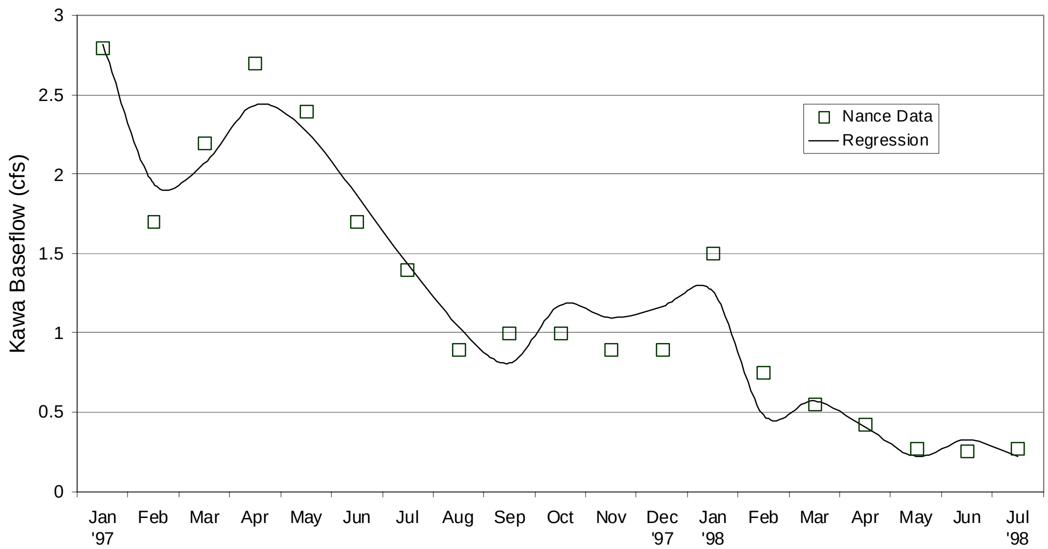

Figure A2. Kawa Stream Baseflow (1997-98)

Approximations for mean seasonal baseflows can be derived from the time-averaged integration of equation *5-5* with seasonal mean rainfall values:

$$\overline{Q}_W = B_D F_6 + B_W (1 - F_6) \qquad (5\text{-}7a)$$

$$\overline{Q}_D = B_D (1 - F_6) + B_W F_6) \qquad (5\text{-}7b)$$

Where:

$$F_6 = \frac{1 - \exp(-6\alpha)}{6\alpha(1 + \exp(-6\alpha))}$$

$$B_D = \frac{bP_D - c_D}{6}$$

$$B_W = \frac{bP_W - c_W}{6}$$

And:

P_D , P_W = respectively, dry and wet season rainfall totals, inch
c_D , c_W = respectively, dry and wet season evaporation and other losses, inch

This seasonal averaging model allows negative seasonal B_D values, i.e., wet season replenishing of dry season storage depletion, while still providing positive dry season baseflow. However, when the net seasonal Q_D or Q_W is negative for the sub-basin or stream segment tributary area, this may indicate that the segment is losing rather than gaining streamflow. It may also mean that the constant evaporation loss term is overstated in the model; in reality, evaporation should decrease as soil moisture is depleted.

The seasonal mean baseflow load contribution (kg/day) of pollutant *k* from land use parcel *j* is:

$$(L_B)_{jk} = 2.447\,(\overline{Q}_D \text{ or } \overline{Q}_W)_j\,(C_B)_{jk}\,, \quad \overline{Q}_D \text{ or } \overline{Q}_W \geq 0$$
$$(L_B)_{jk} = 0\,, \quad \overline{Q}_D \text{ or } \overline{Q}_W < 0 \qquad (5\text{-}8)$$

Where:

$(C_B)_{jk}$ = baseflow concentration of pollutant *k* from land use category *j*, mg/l.

If the baseflow contribution from a land use parcel is not positive, no load is contributed from that parcel.

These expressions for volume and pollutant load contributions to baseflow are used in the Kapa'a Stream TMDL allocation process to disaggregate watershed baseflow volumes and loads to individual land use parcels.

6.0 Streamflow and Water Quality

Streamflow and water quality in this TMDL analysis are calculated as seasonal mean values (for baseflow conditions) or as event mean values (for storm event conditions). Streamflow at the end of segment *j* is the sum of the flow at the beginning of the segment and dispersed baseflow and storm runoff inflows along the length of the segment. Flow at the beginning of the segment is the sum of any point source discharges at the head of the segment and inflow from the immediately upstream segment(s).

$$Q_j = (Q_0)_j + (Q_B)_j + (Q_R)_j \qquad (6\text{-}1)$$
$$(Q_0)_j = (Q_{PS})_j + Q_{j-1}$$

Time-averaged pollutant concentrations increase along the segment length by dispersed baseflow and storm runoff loads and are reduced by instream sedimentation. Instream assimilation rates for phosphorus and nitrogen, as well as suspended solids, are expressed in this analysis as a particle settling velocity but other chemical transformation or biological assimilation mechanisms are mathematically described by the same first-order sediment decay expression.

$$Q\frac{\partial C}{\partial x} + \left(\frac{Q_B + Q_R}{l} + v_s w\right)C = \frac{L_B + L_R}{2.447\,l} \qquad (6\text{-}2)$$

Where:

v_s = settling velocity, ft/sec
w = stream width, feet
l = stream segment length, feet
L = baseflow or storm runoff pollutant load, kg/day.

The integrated form of equation *6-2* provides the end-of-segment concentration:

$$C_j = (C_0)_j \exp(-\beta_j) + \frac{(L_B + L_R)_j}{2.447\overline{Q}}\left(\frac{1-\exp(-\beta_j)}{\beta_j}\right) \qquad (6\text{-}3)$$

$$\beta_j \equiv \frac{(Q_B + Q_R + v_s wl)_j}{\overline{Q}}$$

$$\overline{Q} \equiv \sqrt{(Q_0)_j Q_j}$$

Where streamflow exceeds the full channel flow capacity, Q_C, of a stream segment, the excess overflows to the segment floodplain area and the resulting expression for end-of-segment pollutant concentration becomes:

$$C_j = (C_0)_j (F_1)_j + \frac{(L_B + L_R)_j}{2.447\overline{Q}}(F_2)_j \qquad \overline{Q} > Q_C \qquad (6\text{-}4)$$

$$F_1 \equiv \frac{Q_C}{\overline{Q}}\exp(-\beta_C) + (1 - \frac{Q_C}{\overline{Q}})\exp(-\beta_F)$$

$$F_2 \equiv \frac{Q_C}{\overline{Q}}\left(\frac{1-\exp(-\beta_C)}{\beta_C}\right) + (1 - \frac{Q_C}{\overline{Q}})\left(\frac{1-\exp(-\beta_F)}{\beta_F}\right)$$

$$\beta_C \equiv \frac{Q_B + Q_R}{\overline{Q}} + \frac{v_s w_c l}{Q_C}$$

$$\beta_F \equiv \frac{Q_B + Q_R}{\overline{Q}} + \frac{v_s w_F l}{\overline{Q} - Q_C}$$

Floodplain cross-section in the vicinity of the stream channel is assumed in this analysis to be approximated by the catenary expression:

$$\frac{2D_F}{w_F} = \frac{\cosh(\frac{w_F}{2a}) - 1}{\frac{w_F}{2a}} \qquad (6\text{-}5)$$

Where:

D_F = mid-channel overflow depth
w_F = width of floodplain overflow

The parameter *a* defining the floodplain cross-section is determined from floodplain topography and the solution of equation *6-5*. The cross-sectional area and hydraulic radius of the overflow are expressed as the hyperbolic functions and their expansions:

$$A_x = 2a^2[\frac{w_F}{2a}\cosh(\frac{w_F}{2a}) - \sinh(\frac{w_F}{2a})] \quad \rightarrow \quad \frac{2}{3}a^2(\frac{w_F}{2a})^3 \tag{6-6a}$$

$$R_h = a[\frac{w_F}{2a}\coth(\frac{w_F}{2a}) - 1] \quad \rightarrow \quad \frac{a}{3}(\frac{w_F}{2a})^2 \tag{6-6b}$$

Substitution of these expanded expressions for A_x and R_h into Manning's equation for streamflow provides the expression for width of the floodplain overflow:

$$w_F = \left(\frac{n(\overline{Q} - Q_C)}{1.49\sqrt{s}}\right)^{3/13} (12a)^{5/13} \tag{6-7}$$

7.0 <u>Sediment Retention Ponds</u>

Storm runoff from several of the Kapa'a watershed sub-basin areas is diverted to sediment retention ponds. For small storm events, the entire runoff volume from such areas may be captured and retained so that no discharge to the stream under these conditions will occur. When storm runoff is greater than the available pond storage, the event mean overflow discharge to the stream is:

$$(Q_{OF})_j = \frac{1.008}{t_D}[RA_j - (D_F - D_0)A_P], \qquad RA_j > (D_F - D_0) \tag{7-1}$$

Where:

t_D = time of rainfall duration, hours
D_F = full pond depth, inches
D_0 = initial pond depth, inches
A_P = pond area, acres.

Event-mean pollutant concentrations in the pond discharge are approximated as:

$$(C_{OF})_j = \frac{RA_j C_R + D_0 A_P C_{P0}}{RA_j + D_0 A_P} \tag{7-2}$$

Where:

C_R = stormwater concentration
C_{P0} = initial pond concentration.

8.0 Model Calibration.

Data from the May 5-7, 2002 storm event were used to calibrate the Kapa'a Stream water quality model described above. Total rainfall (Pali Golf Course) for this 3-day period was 5.39 inches, with 27 total hours of rainfall. The calculated storm runoff and pollutant load contributions for this event are presented in Table A.1. The columns, Qnet, SSnet, Nnet, and Pnet, in Table A.1 include the effects of the existing sediment retention ponds. Calculated event mean streamflow and water quality – concentrations of total suspended solids, total nitrogen, and total phosphorus – are displayed in Figure A5.

Table A.1. Kapa'a Flow and Pollutant Load Contributions: May 5-7, 2002

Calibration Event: Runoff Sources				P =	5.39	inch			
Sub-basin	Land Use	Flow	Qnet	TSS	SSnet	TN	Nnet	TP	Pnet
		(cfs)	(cfs)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)
A	Forest/brush	2.96	2.96	1,448	1,448	10.86	10.86	7.24	7.24
A	Highway	0.69	0.69	169	169	1.69	1.69	1.69	1.69
B	Forest/brush	1.01	0	496	0	3.72	0	2.48	0
B	Quarry	20.16	0	246,712	0	98.68	0	49.34	0
B	Roads	0.24	0.00	292	0	0.88	0.00	1.17	0.00
C	Forest/brush	0.36	0.36	177	177	1.33	1.33	0.89	0.89
C	Highway	0.48	0.48	117	117	1.17	1.17	1.17	1.17
D	Eroded	2.99	2.99	69,574	69,574	14.65	14.65	29.29	29.29
D	Highway	0.17	0.17	41	41	0.41	0.41	0.41	0.41
E	Forest/brush	0.40	0.40	197	197	1.48	1.48	0.98	0.98
E	Industrial	0.15	0.15	147	147	0.92	0.92	0.18	0.18
E	Roads	0.40	0.40	493	493	1.48	1.48	1.97	1.97
E	Highway	0.44	0.44	107	107	1.07	1.07	1.07	1.07
F	Forest/brush	1.12	1.12	547	547	4.11	4.11	2.74	2.74
F	Landfill	5.56	5.56	40,838	40,838	54.45	54.45	13.61	13.61
F	Roads	0.26	0.26	321	321	0.96	0.96	1.28	1.28
G	Forest/brush	2.02	2.02	987	987	7.41	7.41	4.94	4.94
G	Industrial	2.90	2.90	2,841	2,841	17.76	17.76	3.55	3.55
G	Highway	0.33	0.33	80	80	0.80	0.80	0.80	0.80
H	Forest/brush	2.50	2.24	1,224	992	9.18	7.53	6.12	4.99
H	Landfill	3.12	2.79	22,880	18,542	30.51	25.04	7.63	6.22
H	Roads	0.20	0.18	250	203	0.75	0.62	1.00	0.82
I	Landfill	0.53	0.53	3,893	3,893	5.19	5.19	1.30	1.30
I	Roads	0.25	0.25	308	308	0.93	0.93	1.23	1.23
J	Forest/brush	0.51	0.51	248	248	1.86	1.86	1.24	1.24
J	Landfill	2.62	2.62	19,244	19,244	25.66	25.66	6.41	6.41
J	Highway	0.53	0.53	130	130	1.30	1.30	1.30	1.30
K	Landfill	2.45	2.45	17,975	17,975	23.97	23.97	5.99	5.99
K	Roads	0.10	0.10	123	123	0.37	0.37	0.49	0.49
L	Landfill	3.32	3.15	24,379	22,083	32.51	29.60	8.13	7.39
L	Industrial	2.50	2.37	2442.4	2,212	15.26	13.90	3.05	2.78
L	Roads	0.36	0.34	436	395	1.31	1.19	1.74	1.59
	Totals:	61.63	39.29	459,119	204,433	372.59	257.67	170.44	113.55

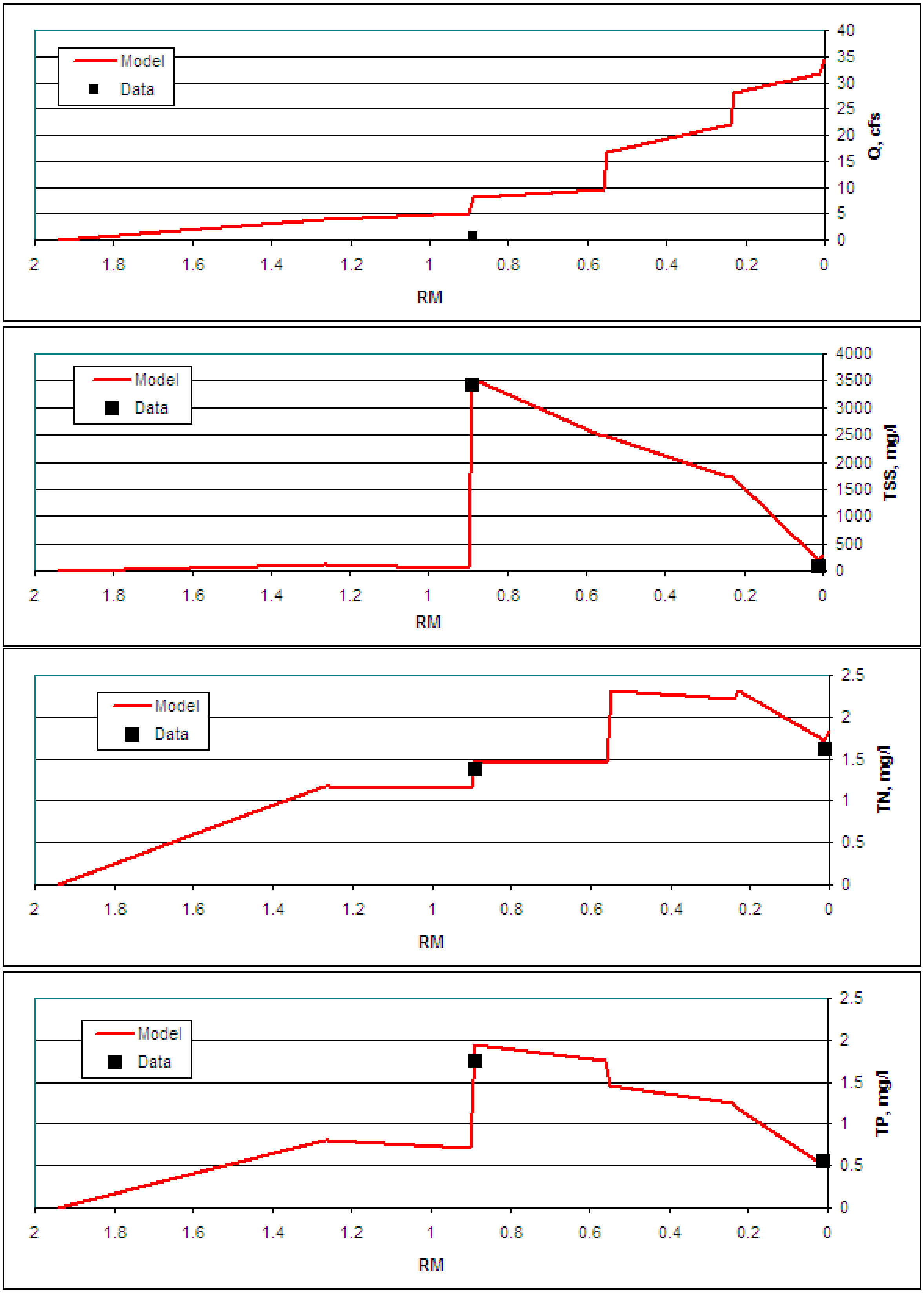

Figure A5. Kapa'a Stream Flow and Water Quality: May 5-7, 2002

9.0 Water Quality Targets.

Hawaii's water quality standards for concentrations of conventional pollutants are expressed as a three term probabilistic function:

a) The geometric mean concentration shall not exceed a designated value (C_G),
b) Concentrations shall not exceed a value (C_{10}) more than 10% of the time, and
c) Concentrations shall not exceed a value (C_2) more than 2% of the time.

A proposed interpretation of this standard for TMDL purposes is the following. The geometric mean criterion can be expressed:

$$p\ln(C_d) + (0.9 - p)\ln(C_{w9}) + 0.08\ln(C_8) + 0.02\ln(C_{w2}) \le \ln(C_G) \qquad (8\text{-}1)$$

Where:

C_{w2} = geometric mean of the highest 2% of daily concentrations
C_8 = geometric mean of the next highest 8% of daily concentrations
C_{w9} = geometric mean of concentrations during remaining days of stormwater runoff
C_d = geometric mean of concentrations during days without stormwater runoff
p = fraction of days without stormwater runoff

And:

$C_{w9} \approx (C_d \bullet C_{10})^{1/2}$
$C_8 \approx (C_{10} \bullet C_2)^{1/2}$
$C_{w2} \approx (C_2 \bullet mC_2)^{1/2}$
mC_2 = highest concentration occurring.

With these approximations, equation *8-1* can be rewritten in terms of the standard:

$$(0.45 + \frac{p}{2})\ln(C_d) + (0.49 - \frac{p}{2})\ln(C_{10}) + 0.06\ln(C_2) + 0.01\ln(m) \le \ln(C_G) \qquad (8\text{-}2)$$

Equation *8-2* is rearranged to define a geometric mean concentration (C_d) for dry-weather conditions in terms of the water quality standard:

$$\ln(C_d) \le \frac{\ln(C_G) - (0.49 - \frac{p}{2})\ln(C_{10}) - 0.06\ln(C_2) - 0.01\ln(m)}{(0.45 + \frac{p}{2})} \qquad (8\text{-}3)$$

The *m*-term will reduce the value of C_d by about 1 or 2 percent for values of $m<10$. It is an identifiable component of the TMDL margin of safety.

Two sets of TMDLs can be developed, for each of the different wet and dry season conditions and standards, that satisfy the C_2 criterion for the 2% return frequency storm event, the C_{10} criterion for the 10% return frequency event, and the C_d criterion for dry-weather baseflow. These TMDLs will achieve the Hawaii water quality standards and account for both critical conditions and seasonal variations. Furthermore, the association of each TMDL with a defined storm event or baseflow condition will provide explicit design guidance for TMDL implementing authorities.

In some cases, concentrations of some pollutants, e.g., nitrogen, herbicides, are higher during dry weather periods than during stormwater runoff. In these cases the water quality standards not to be exceeded more than 2% or 10% of the time will apply to dry weather baseflow rather than to stormwater runoff conditions and the geometric mean criterion would be expressed:

$$0.02\ln(C_{d2}) + 0.08\ln(C_8) + (p-0.1)\ln(C_{d9}) + (1-p)\ln(C_w) \le \ln(C_G) \qquad (8\text{-}4)$$

$C_{d9} \approx (C_G \bullet C_{10})^{1/2}$
$C_8 \approx (C_{10} \bullet C_2)^{1/2}$
$C_{d2} \approx (C_2 \bullet mC_2)^{1/2}$
mC_2 = highest concentration occurring.

By the same substitution and rearranging of terms outlined above, dry weather and wet weather concentration criteria can be developed:

$$\ln(C_d) \le \frac{(\frac{p}{2}-0.05)\ln(C_G) + (\frac{p}{2}-0.01)\ln(C_{10}) + 0.06\ln(C_2) + 0.01\ln(m)}{p} \qquad (8\text{-}5)$$

$$\ln(C_w) \le \frac{(1.05-\frac{p}{2})\ln(C_G) - (\frac{p}{2}-0.01)\ln(C_{10}) - 0.06\ln(C_2) - 0.01\ln(m)}{(1-p)} \qquad (8\text{-}6)$$

Where C_d is the geometric mean of dry weather concentrations and C_w is the geometric mean of concentrations during days of stormwater runoff.

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